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## Human Factors; Inclusive eServices for all: Optimizing the accessibility and the use of upcoming user-interaction technologies

Reference

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# Foreword

This ETSI Guide (EG) has been produced by ETSI Technical Committee Human Factors (HF).

# Introduction

Europe, as well as other economically developed areas, is facing a number of social and economic challenges including an ageing population and high expectations with regard to quality of life, in particular in healthcare, environmental and transportation concerns. These changes in society are also reflected in new requirements for products and services resulting from changing sensory, cognitive and physical abilities of their users.

Experience shows a predominant pattern of products and services being offered that do not take sufficiently into account the needs of people with mild or severe impairments. This tendency contributes to create gaps between people with disabilities and the average population regarding the usage of Information and Communication Technologies (ICT). Two reasons for this state of affairs can be identified. First, companies do not see a business case in offering barrier-free products. Secondly, product and eService developers are often unaware of the requirements of customers with impairments, neither are they familiar with appropriate design solutions that in many cases are not very demanding in terms of research and development (R&D) and production costs.

The motivation for the development of barrier-free services and technologies can be regarded as demand driven, i.e. users, organisations and policy makers express needs that they are not able to satisfy today with existing eService offerings and products. Adopting a Design for All approach should be perceived as an opportunity as it can frequently lead to innovative design solutions that bring benefits to all users, increasing the overall attractiveness of product offerings.

The present document addresses relevant user requirements by taking a long-term approach in ensuring that new ICT will consider the various needs of all users (including older users and those with disabilities) at the time when the technology is first deployed, not as an afterthought as has been the case for many significant previous technological developments.

Building a Design for All approach into the design process of devices and services will ensure that these products have the broadest possible range of application by users with different abilities and users in different contexts. Fully utilising the provisions in the present document will enable manufacturers and suppliers to demonstrate that they have understood and overcome potential accessibility barriers that would otherwise have been created by new interaction technologies that they are using. Adopting such a planned inclusive design approach can be utilised as a positive marketing message that can be given when introducing such products.

Furthermore, adopting the provisions given in the present document will also significantly reduce the risk that manufacturers and suppliers who employ future interaction technologies will introduce products that fail to meet the needs of all sectors of society. Such use of the provisions will thus help industry to avoid the twin penalties of:

- the damage to corporate image that results from the introduction of products that are seen to discriminate against and exclude sectors of society that command widespread public sympathy;

- the very high costs of having to retrospectively and rapidly re-engineer products in order to ensure that they no longer exclude sectors of society that have already been alienated by previous versions of the product.

Adopting the provisions in the present document may reduce the likelihood that device manufactures and eService providers become the subject of regulation. By doing so, they will be well prepared to comply with any standards or regulation that may in the future be implemented to achieve an inclusive approach to private and public procurement.

# 1 Scope

The present document provides guidance for the user interaction design of telecommunication devices and services that are likely to become available for large-scale rollout to consumers in the next five to ten years. In particular, the document identifies provisions that have to be made in order to ensure that forthcoming interaction technologies deployed in devices and services will be usable by all users including older people and/or people with disabilities.

The present document lists user interaction technologies likely to be employed in future devices and services in the form of a technology roadmap. For each identified technology, key characteristics specified include:

- user requirements impacted by the technology;
- benefits and accessibility barriers that will result from deployment;
- solutions related to accessibility barriers (both those benefiting disabled users only as well as those being useful for all users in different contexts).

Measures are identified that need to be addressed prior to the large-scale implementation of those technologies in order to ensure their usability by users with the widest range of characteristics.

Within the scope of the document are those interaction technologies that are likely to be used in information and communication products and services and are likely to achieve a mass-market breakthrough between 2010 and 2020.

Interaction technologies that are exclusively used in:

- stand-alone, off-line products and services;
- assistive devices;
- safety and security-related products and services;

are not within the scope of the present document, even though the guidelines may also apply to some of them.

General user interface design issues (e.g. cognitive workload) that affect the usability and accessibility of user interfaces for eServices are also outside of the scope of the present document.

The intended readers of the present document are the designers, manufacturers and suppliers of all ICT products and services that may use new user interaction technologies in their future offerings. Researchers benefit from the present document by integrating its findings into their research at a very early stage.

It is expected that the present document should be utilised in the earliest stages of the planning of a new product or eService to ensure that the measures proposed can be taken into account during all stages of the product design and implementation process. Such usage should ensure that the resulting product or eService is as barrier free in its design as possible.

# 2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

## 2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

## 2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI EG 202 116: "Human Factors (HF); Guidelines for ICT products and services; "Design for All"".

[i.2] ETSI TR 102 849: "Human Factors (HF); Inclusive eServices for all; Background analysis of future interaction technologies and supporting information".

[i.3] ISO TR 29138-1: "Information technology - Accessibility considerations for people with disabilities - Part 1: User needs summary".

[i.4] ISO 9241-920: "Ergonomics of human-system interaction - Part 920: Guidance on tactile and haptic interactions".

[i.5] The Center for Universal Design, NC State University.

NOTE: Available at http://www.design.ncsu.edu/cud/about_ud/udprinciplestext.htm.

[i.6] ISO 9241-20: "Ergonomics of human-system interaction. Accessibility guidelines for information/communication technology (ICT) equipment and services".

[i.7] ETSI EG 202 417: "Human Factors (HF); User education guidelines for mobile terminals and services".

[i.8] ETSI TR 102 068: "Human Factors (HF); Requirements for assistive technology devices in ICT".

[i.9] ETSI ES 202 076: "Human Factors (HF); User Interfaces; Generic spoken command vocabulary for ICT devices and services".

# 3 Definitions and abbreviations

## 3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

**augmented reality:** augmented reality displays are those in which the image is of a primarily real environment, which is enhanced, or augmented, with computer-generated imagery

NOTE: More generally, augmented reality can be defined as any media that is specific to user's location or context, which is displayed in order to augment or enhance user's specific reality.

**Design for All:** design of products to be accessible and usable by all people, to the greatest extent possible, without the need for specialized adaptation

**eService:** See service.

**eService cluster:** collection of multiple (electronic) services aggregating into one (joint, often more abstract) eService

**haptic:** passive perception through the sense of touch

**input modality:** sense or channel through which a human can receive the output of an ICT device or service

EXAMPLE: Visual modality.

**interaction modality:** input modality or output modality

**interaction technology:** See user interaction technology.

**modality:** See sensory modality.

**multimodal:** relating to multiple input modalities and/or output modalities

**multimodality:** simultaneous support of multiple input modalities and/or output modalities

**output modality:** channel through which a sensor, device or service can receive the input from the human

EXAMPLE: Kinaesthetic modality.

**sensory modality:** sense or channel through which a human can send input to or receive output from an ICT device or service

EXAMPLE: Kinaesthetic modality.

**service:** complete capability, including terminal equipment functions, for communication between users, systems and applications, according to agreed protocols

**tactile:** perception through the sense of touch while actively moving parts of the body

**user interaction technology:** any instrument, equipment or technical system enabling a user to interactively communicate with a device or service

**user interface:** physical and logical interface through which a user communicates with a device or service

## 3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

| | |
|---|---|
| AAC | Augmented and Alternative Communication |
| ADC | Analogue-to-Digital Converter |
| AEC | Acoustic Echo Cancellation |
| AR | Augmented Reality |
| AT | Assistive Technology |
| AVSR | Audio-Visual Speech Recognition |
| BSS | Blind Source Separation |
| CSCW | Computer Supported Co-operative Work |
| DOF | Degrees of Freedom |
| DSR | Distributed Speech Recognition |
| DTW | Dynamic Time Warping |
| DVB-S | Digital Video Broadcasting, Satellite television |
| DVD | Digital Versatile Disk (also known as digital video disk) |
| DVDD | Direct Volume Display Devices |
| FOV | Field Of View |
| GPS | Global Positioning System |
| GUI | Graphical User Interface |
| HD | High Definition |
| HDTV | High Definition Television |
| HMD | Head-Mounted Displays |
| HRTF | Head-Related Transfer Function |
| HUD | Head-Up Displays |
| ICT | Information and Communication Technologies |
| IR | Infrared |
| LCD | Liquid Crystal Display |
| LED | Light-emitting diode |
| MEMS | Micro-Electromechanical Systems |

| | |
|---|---|
| NFC | Near Field Communication (wireless) |
| NGN | Next Generation Network |
| OIV | Obscured Information Visualization |
| OLED | Organic Light Emitting Diode |
| PC | Personal Computer |
| PDF | Portable Document Format |
| PIR | Passive Infrared Sensor |
| QoS | Quality of Service |
| R&D | Research and Development |
| RF | Radio Frequency |
| RFID | Radio-Frequency Identification |
| RSVP | Rapid Serial Visual Presentation |
| SID | Spatially Immersive Display |
| TTS | Text-To-Speech |
| UI | User Interface |
| WAI | Web Accessibility Initiative |
| WCG | Wide-Colour Gamut |
| WFS | Wave Field Synthesis |

# 4 Rationale

An analysis of the deployment of existing services and their user interfaces shows a common pattern of addressing the requirements of older people and those with disabilities significantly after the initial availability of innovative new user interaction technologies. This pattern is so common because new and sometimes disruptive technologies are usually developed for and targeted at mainstream consumers, or at narrow target groups of early adopters, the wealthy or the technology-aware.

Those new and/or disruptive technologies did not initially include the easy accommodation of the requirements of people with disabilities. Subsequent measures for compensating these shortcomings have often been late and costly. Examples of technologies deployed without appropriate consideration for the requirements of users with disabilities are listed in table 4.1.

**Table 4.1: Examples of accessibility gaps in consumer products**

| Technology | Accessibility weaknesses |
|---|---|
| Personal computer (PC) | The first PCs with character-based user interfaces were easily usable by blind users with a Braille-keyboard device. The advent of graphical user interfaces (GUI) suddenly excluded blind users until screen readers became available. |
| The Internet | The problems are similar to the ones described for the PC, as early communications services (e.g. gopher services and first E-mail services) were text based and were later replaced by graphical interfaces such as web browsers. The Web Accessibility Initiative (WAI) stepped in late, and took long to evolve if compared to the very dynamic development of web technologies. |
| Document file formats | Documents produced in image-based versions of the PDF-format are not accessible to blind users. |
| Digital music or media players | Many classic cassette players have mechanical switches and mechanisms that rely on the physical insertion and turning of a cassette to select different audio segments. However, modern digital music players are increasingly relying on on-screen interfaces with few, if any, physical controls to offer suitable feedback and are therefore unsuitable for people with poor eyesight. |
| Biometric systems | Biometric applications are more and more used for supporting authorisation and access control. People with disabilities (e.g. physical or speech impairments) are likely to face barriers as users of these systems. Multimodality may contribute to accessibility in this field, as well as to higher levels of performance and user acceptance. |

The introduction of forthcoming applications and technologies such as ambient intelligence, ubiquitous communications and others enabled by Next Generation Networks (NGN) should not follow the same pattern, but adopt a true "Design for All" approach instead. This implies that the specific requirements of older users and users with disabilities should be taken into account prior to the large-scale introduction of such technologies. These requirements lead to provisions that should be made prior to or at the introduction of new technologies in order to meet the needs of all users.

Emerging user interaction technologies may pose interaction challenges that still remain unaddressed by available standards on generic accessibility of ICT products and services. One of the reasons for this may be that certain modalities (e.g. haptic/tactile) have acquired an increasing importance in user interfaces, whereas previously they have been used mainly as a complement to other modalities (e.g. visual and auditory). Furthermore, new interaction paradigms (e.g. augmented reality) still lack a holistic analysis of their accessibility implications. The present document addresses these and further issues attempting to identify relevant future interaction technologies and appropriate Design for All provisions.

Implementing the provisions in the present document can result in a higher average revenue per user for eService providers and an increased customer base for device manufacturers. Ensuring that the needs of older users and users with disabilities are addressed in the initial release of a product or eService will avoid the additional re-development costs incurred by the need to address this in later product releases.

Adapting new services and devices according to these provisions will result in inclusion for all users, regardless of their age and impairments. Delivering services and devices that are accessible from the start will empower users, strengthening trust in their ability to master new technologies designed to improve their quality of life. Switching to a new eService or device will be easier for users when the provisions in the present document are adopted.

Previous ETSI work has produced an excellent basis for educating device and eService designers about the requirements of older users and users with disabilities by illustrating design principles for barrier-free products and services. One example of the many ETSI publications on barrier-free design is [i.1].

However, the current literature, including the documents published by ETSI, largely focuses on existing technologies. The developers of innovative new technologies may be unaware of these resources and, if they are, it may not be possible to apply guidance from these resources to the development of new technologies. The present document addresses both the need for an analysis that anticipates the demands of new technologies and for the development of guidance that is suitable for these forthcoming technologies.

# 5 Method

The technology roadmaps and technology properties listed in clause 6 were identified using a combination of desk research and expert consultation. It included literature research and interviews with experts and stakeholders. The development of the Design for All provisions in the present document resulted from an analysis of the options which designers and manufactures have during the design of new services or access devices. Details of the working method are described in [i.2].

Existing and forthcoming eServices were analyzed and grouped into eService clusters such as eHealth, eGovernment and eLearning (see table 5.1). In order to systematically identify potential accessibility barriers to those eServices and appropriate solutions, each interaction technology listed in clause 6 has been assessed against a set of generic user requirements related to ICT accessibility. The main aim was to identify those user requirements that may create accessibility barriers when making use of novel and emerging interaction technologies.

**Table 5.1: eService Clusters**

| eService Clusters | Explanations |
|---|---|
| eGovernment services | eGovernment services include authentication services, electronic application for id-cards, passports, driver's licenses, etc., remote payment of supplies like energy and water, as well as eTax services that include the electronic filing of tax forms, electronic payment of taxes and communication with tax offices. |
| eHealth services | eHealth services are, among others telecare services, remote health monitoring, access to patient data, remote diagnosis and electronic prescription services. |
| Social services delivered through electronic means | Social services delivered through electronic means comprise remote supervision of people in need, ICT-supported caretaking (incl. robotics applications), social communities, electronic support for old people in need, messaging services, sharing services for pictures, video and music, ICT supported access to personalized human assistance. |
| Home automation services | Home automation services supply services, smart homes, energy management, light and entertainment management in the house, remote building control. |
| eBanking services | eBanking requires secure transmission and transaction services, remote authentication services as well as data- and secure information delivery to customers (e.g. for bank statements). |

| eService Clusters | Explanations |
|---|---|
| Electronic purchasing services | Electronic purchasing services include and require electronic payment, authentication services, information and database search, and secure transactional communication, electronic travel booking and management, download of electronic content (music, video) and applications (app stores). |
| Information services | Including news, sports results and information retrieval. |
| eLearning services | eLearning services comprise, among others, remote access to school and university databases, virtual classrooms and remote teaching, remote access to museums. |
| Mobile office applications and services | Mobile office applications include remote access to office data, Computer Supported Co-operative Work (CSCW) environments, electronic publishing services, remote translation services, messaging services, remote conference services, mobile email access, remote storage of personal data, etc. |
| eGames and entertainment services | eGames and Entertainment comprise all sorts of interactive games played with remote partners of communication networks, delivery of information and entertainment content to customers, electronic pets, eSex services and remote support and monitoring of activities like exercising. |

The primary source of this set of accessibility requirements was [i.3]. Other relevant standards on ICT accessibility have been applied where appropriate, such as [i.1]. As stated in clause 4, emerging user interaction technologies may pose interaction challenges that still remain unaddressed by available standards on generic accessibility to ICT. Additional sources that have been used include:

- Accessibility standards which are specific to such modality or user interaction technology, such as [i.4].
- A literature review of scientific evidence on modality/technology specific ergonomics.

The outcome of the final step was the definition of provisions that have to be made prior to or at the introduction of each new technology in order to enable the support of emerging services for older and/or disabled users and citizens. In addition, interaction technology areas needing human-factors harmonization/standardization work have been identified.

The technologies within the scope of the present document are predominantly related to the user interaction components of communication enabling devices. Examples of these user interaction technologies are 3-dimensional touch interfaces or wallpaper projection. The functional components of those devices that enable the communication of the device with eServices such as data-exchange protocols and networks are within the scope of the present document only to such an extent as they allow for the employment of novel types of interaction technologies.

# 6 Roadmaps of user interaction technologies

## 6.1 General

### 6.1.1 Contents of the user interaction technology roadmaps

The user interaction technology roadmaps included in this clause group upcoming technologies according to interaction modalities (e.g. acoustic/audio input, acoustic/audio output). Within each roadmap, technologies are organised in sub categories where appropriate (e.g. advanced microphones and voice-input technologies are sub categories on the roadmap for acoustic/audio input technologies). The individual technologies are positioned along a time dimension covering ten years according to their expected mass-market availability for the general consumer. Estimates of the time of mass-market availability are based on expert interviews and literature studies. As such, they represent the best estimates available at the time of writing. The indicated dates should not be relied upon if making any important design or deployment decisions, as it will always be necessary to seek more current mass-market availability information before making such decisions.

Technologies that are potentially relevant for more than one roadmap are marked with an asterisk to indicate that they are being dealt with in detail in the context of another roadmap (e.g. the technology 'communications badge' is listed on the roadmap acoustic/audio output with an asterisk, and it is being dealt with in detail in roadmap acoustic/audio input).

An alphabetic listing of all the user interaction technologies covered in the present document appears in table A.1.

### 6.1.2 Contents of the technology properties

Each roadmap is followed by tables with various properties of the technologies covered by the roadmap. Table 6.1 gives explanations of the rows of those tables.

**Table 6.1: Categories of technology property tables**

| Table field | Explanations |
|---|---|
| Name | The generic name by which the technology is commonly known. |
| Description | A brief description of the user interaction technology covered in the table. This may include reference to other technologies in order to point out similarities and/or differences. In some cases, a table may actually cover a group of related technologies that exhibit a significant common characteristic that is clear and obvious. |
| Mass market deployment | The expected timeframe ('by 2012', 'by 2015', 'after 2015') within which the technology will have matured to the extent of being ready for mass-market availability for mainstream customers. |
| Sub category | The sub category of the interaction modalities the technology in question is grouped in. Technologies that have significant similarities from an end-user perspective are grouped into the same sub category. |
| Related technology | Technologies or sub categories, that are in one or more ways related to the technology in question (e.g. by presenting an alternative, by possessing certain similarities, by representing a technological basis a technology relies on, or by contributing to the technology in some way). |
| User requirements | User requirement, adapted from [i.3]:<br>User needs summary that for a given technology may either:<br>- be unmet;<br>- be poorly met;<br>- be partially met (when other common alternative technologies fail to meet the requirement);<br>- be fully met (when other common alternative technologies fail to meet the requirement well or at all). |
| Accessibility barriers | Potential characteristics of the technology that create obstacles for older people or people with disabilities, or for all users in certain contexts of use. |
| Solutions related to accessibility barriers | Any solutions to the accessibility barriers identified above (wherever meaningful, this also addresses the "unmet" or "poorly met" user requirements identified above). |
| Cultural issues | Potential positive or negative issues when the technology is used by people from different cultural backgrounds or when the product is used in particular cultural environments. |
| Benefit for all users | Benefits that the use of this technology presents to all users (frequently in comparison to the use of other existing or alternative technologies). |
| Benefits for older people and people with disabilities | Benefits that the use of the technology in question presents to users with certain impairments, linking the benefits to the type of disability or need (frequently in addition to any general benefits identified in "Benefits for all users"). |
| Deployment pros | Potential benefits to those deploying the user interaction technology (in terms of factors such as ease of deployment, cost, ability to offer new services, etc.). |
| Deployment cons | Any technical and commercial problems of deploying the technology as well as any potential disadvantages to users, not related to accessibility, of deploying this technology. |
| Implementation requirements | Factors that need to be taken into account before the technology in question is used e.g. the need for other technologies to be developed before this technology can be successfully deployed, or some non-technical factors like the need for the design to meet various fashion criteria. |
| Harmonization | Reference to relevant existing standards or to the need for new standards to be developed. |

### 6.1.3 Key Design for All solutions

One central element of the technology property tables as described in clause 6.1.2 is the "solutions related to accessibility barriers" field, describing Design for All provisions that ought to be implemented prior to the mass-market introduction of a product containing a particular user interaction technology. Table 6.2 lists solutions commonly recurring in the technology property tables, together with explanations and references.

**Table 6.2: Key Design for All solutions**

| Solution | Explanation | Reference |
|---|---|---|
| Multimodal presentation | Use different modes (visual, acoustic, tactile) for redundant presentation of information. Also support simultaneous use of different modes. | [i.5] |
| Multimodal control | Use different modes (visual, acoustic, tactile) for providing control location and function information. | [i.5] |
| Independent control | Provide independent controls for different output channels. | [i.6] |
| Multimodal feedback | Provide effective and multi-modal feedback during and after task completion. | [i.5] |
| Object navigation | Allow navigating among presented objects (e.g. visual objects, haptic/tactile). | Adapted from [i.6] |
| Object adjustability | Allow adjusting the size of displayed objects. | [i.6] |
| Selective magnification | Allow magnifying portions of a visual or tactile display. | Adapted from [i.6] |
| Displayed information adjustability | Allow adjusting characteristics of displayed information (e.g. contrast, volume, force, size). | Adapted from [i.6] |
| Equivalent simultaneous control | Provide equivalent control through different modes (kinaesthetic, vocal, etc.). Also support simultaneous use of different modes. | Adapted from [i.6] |
| User limitation compensation | Compensate for limitations in user's actions over the system (e.g. compensate tremors, robust voice recognition systems for people with speech impairments). | Adapted from [i.6] |
| Reasonable operating forces | Use reasonable operating forces. | Adapted from [i.6] |
| Sustained effort minimization | Minimize sustained physical effort. | [i.6] |
| Low complexity | Eliminate unnecessary complexity. | [i.6] |
| Consistency with expectations | Be consistent with user expectations and intuition. | [i.6] |
| Training need minimization | Minimize the need for training. | [i.6] |
| Barrier-free user education | Barrier-free provision of user-education materials (e.g. user guides). | [i.7] |
| Describability | Differentiate elements in ways that can be described (i.e. make it easy to give instructions or directions). | [i.6] |
| Standardized Assistive Device connection | Provide for a standardized option to connect assistive devices. | [i.8] |

## 6.2 Acoustic/audio input technologies roadmap

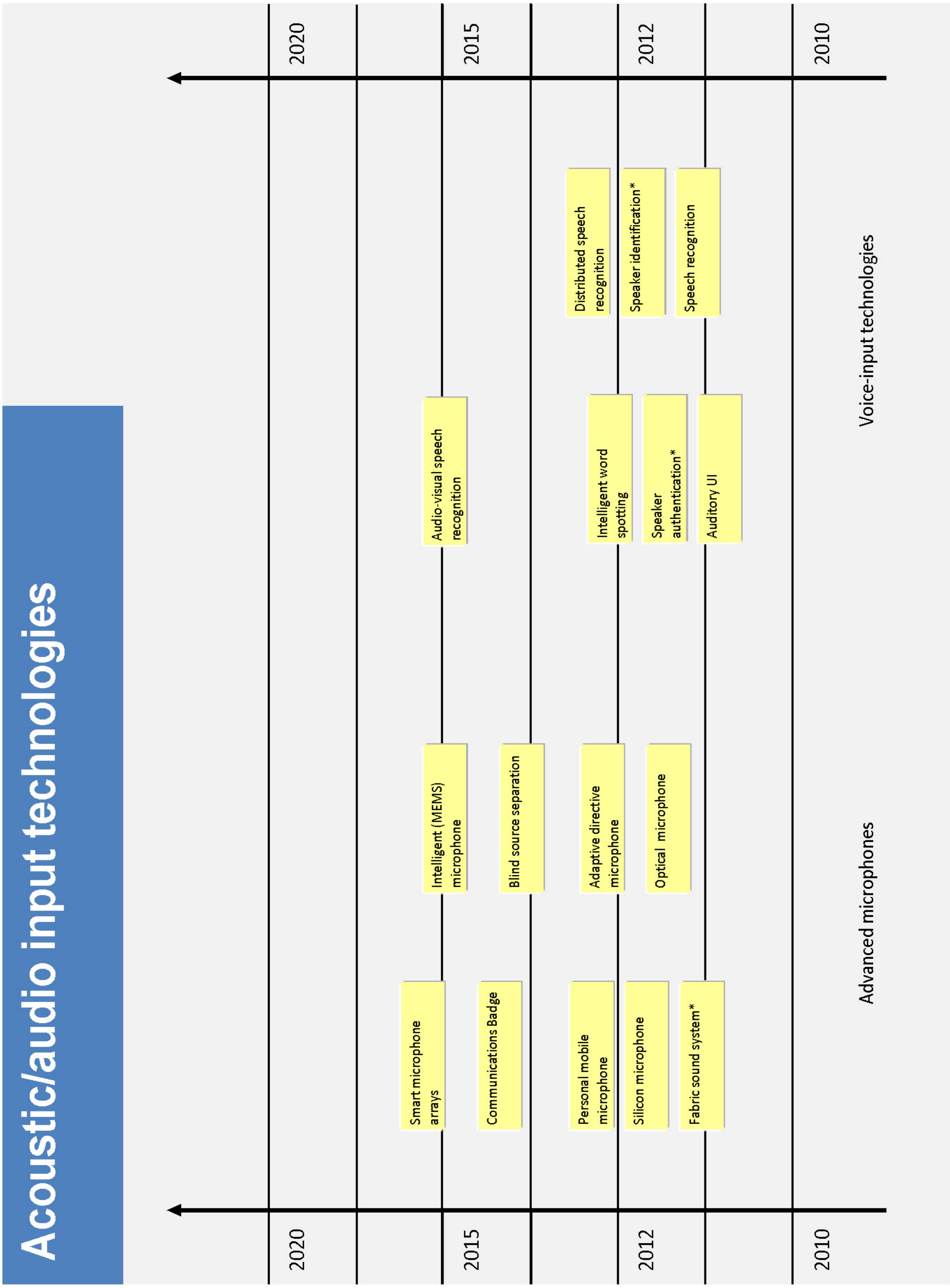


**Figure 6.2.1: Acoustic/audio input technologies roadmap**

The main areas of innovation in the area of acoustic/audio input technologies are advanced microphones and voice-input technologies. These technologies will support voice-based interaction with and the voice control of a variety of novel products and eServices such as smart homes.

Key developments in this area are:

- miniaturization and form factors;
- improved sound quality;
- improved privacy;
- improved speech recognition.

These technologies have the potential to increase accessibility, e.g. by improving the voice control of devices and eServices by visually impaired people. However, they may cause problems for users with severe impairments or for all users in certain contexts:

- Voice-interaction dialogues are not suited for deaf users or users who cannot speak.
- Voice-interaction dialogues may not support severely hard-of-hearing users.
- Voice control may not operate sufficiently well for users with severe speech impairments.
- Visually impaired users may find it difficult to identify controls (location of on, off) and indications (status of device, transmitting or idle).
- Those technologies may not operate well in noisy environments.
- Users may be inhibited when using voice to interact in public spaces.
- The user's voice input may be perceived as unwelcome and anti-social by others in public spaces.

Solutions for these and other accessibility barriers identified for individual or several acoustic/audio input technologies are listed in the tables below and include:

- Multimodal controls and indications offering access to a device or eService by means of more than one sensory modality, e.g. the provision of non-voice interaction options that duplicate the features of the voice-based user input.
- Reduced complexity modes ensuring that important and/or critical functionality is easily accessible by all users including those with severe impairments.
- When interaction is based on voice recognition, users with speech impairments should either receive specific support (e.g. using recognition systems adapted to their needs) or have an alternative input modality available.

NOTE: Some acoustic/audio input technologies listed in figure 6.2.1 with an asterisk next to their names are dealt with in detail in the context of other roadmaps: Fabric sound system in roadmap acoustic/audio output technologies (figure 6.8.1); speaker authentication and speaker identification combined as speaker recognition in roadmap recognition/mood/arousal-based input technologies (figure 6.5.1).

Table 6.2.1 gives an alphabetical listing of the technologies covered in this clause.

**Table 6.2.1: Overview of acoustic/audio input technologies**

| User interaction technology | Sub category | Table |
|---|---|---|
| Adaptive directive microphones | Advanced microphones | 6.2.4 |
| Audio-visual speech recognition | Voice-input technologies | 6.2.14 |
| Auditory UI | Voice-input technologies | 6.2.10 |
| Blind source separation | Advanced microphones | 6.2.6 |
| Communications badge | Advanced microphones | 6.2.7 |
| Distributed speech recognition | Voice-input technologies | 6.2.13 |
| Intelligent (MEMS) microphones | Advanced microphones | 6.2.8 |
| Intelligent word spotting | Voice-input technologies | 6.2.12 |
| Optical microphones | Advanced microphones | 6.2.2 |
| Personal mobile microphones | Advanced microphones | 6.2.5 |
| Silicon microphones | Advanced microphones | 6.2.3 |
| Smart microphone arrays | Advanced microphones | 6.2.9 |
| Speech recognition | Voice-input technologies | 6.2.11 |

**Table 6.2.2: Optical microphones**

| Characteristic | Definition |
|---|---|
| Name | Optical microphones |
| Description | Optical microphones are usually implemented as two-chip solutions with one light-emitting and one light-receiving sensor. The basic idea of an optical microphone is that a diaphragm that is vibrating due to sound incidence is sampled by a ray of light that as a result is modulated either in intensity or in phase. Basic components of the optical microphone are the light-reflecting diaphragm, which consists of aluminium, the light source (an LED), the photo detector (photo diode) and the 'optical head' that is responsible for directing the light to and from the diaphragm at a very small angle. The focus of current research combines an optical displacement detection scheme with a unique design for achieving directionality (omni-directional and directional responses). |
| Mass market deployment | By 2012. |
| Sub category | Advanced microphones. |
| Related technology | Intelligent (MEMS) microphone.<br>Adaptive directive microphone. |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Status and feedback information may not be perceivable by people with severe visual impairments.<br>- Area covered by directional response may not be obvious and/or accessible to users with disabilities. |
| Solutions related to accessibility barriers | - Multimodal feedback: provide optional mode with audio indications of status feedback (e.g. low battery or connection established or terminated) as users may have problems understanding feedback related to the status of the microphone if this status information is presented in a modality that the user cannot perceive.<br>- Ensure physical accessibility of area covered by the microphone (e.g. by wheelchairs).<br>- If used to achieve directional responses, the required sound-capturing area vis à vis the microphone should be indicated in an accessible and multimodal way. |
| Cultural issues | None identified |
| Benefit for all users | - Allows new form factors.<br>- Suitable for harsh and hazardous environments.<br>- This technology can be used to achieve directionality improving the signal-to-noise ratio. |
| Benefits for older people and people with disabilities | - Improves quality of voice communications for people with speech impairments or low voices and for hearing impaired people. |

| Characteristic | Definition |
|---|---|
| Deployment pros | - Offers new form factors and may be combined with photo-electric technologies for charging the battery. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

### Table 6.2.3: Silicon microphones

| Characteristic | Definition |
|---|---|
| Name | Silicon microphones |
| Description | Silicon microphones are micro-electromechanical systems (MEMS) that are constructed on a single silicon wafer using processes originally developed for making ICs. The technology allows further miniaturization of today's electret microphones (chip sizes are in the range of 1x1 mm) and the integration of electronic circuitry (amplifier, analog-to-digital converter (ADC), etc.) on the same chip. Both features are very interesting for mobile device applications where size and radio frequency interference is very critical. |
| Mass market deployment | By 2012 |
| Sub category | Advanced microphones |
| Related technology | Optical microphone<br>Intelligent (MEMS) microphone<br>Personal mobile microphone |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Controls may be difficult to locate for severely visually impaired users.<br>- Status of controls may be difficult to determine for severely visually impaired users. |
| Solutions related to accessibility barriers | - Multimodal feedback: provide optional mode with audio indications of status feedback (e.g. low battery or connection established or terminated) as users may have problems understanding feedback related to the status of the microphone if this status information is presented in a modality that the user cannot perceive. |
| Cultural issues | None identified |
| Benefit for all users | - Improved voice transmission for miniaturized devices. |
| Benefits for older people and people with disabilities | - Improves quality of voice communications for people with speech impairments or low voices and for hearing impaired people. |
| Deployment pros | - Offers new miniaturised form factors. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.2.4: Adaptive directive microphones**

| Characteristic | Definition |
|---|---|
| Name | Adaptive directive microphones |
| Description | Adaptive directive microphones address the problem that hands-free telecommunication suffers from low signal-to-noise ratios in high ambient noise conditions and from room reverberation that decreases the intelligibility of the recorded speech. Adaptive directive microphones suppress ambient noise efficiently (10 dB to 16 dB) by means of adaptive filtering of the at least two microphone signals and a control unit to change the at least one adaptation parameter such that the sum of interference power is reduced. The resulting directional patterns are used to enhance the speaker's voice and to suppress ambient noise. |
| Mass market deployment | By 2015 |
| Sub category | Advanced microphones |
| Related technology | Personal mobile microphone<br>Intelligent (MEMS) microphone<br>Optical microphone<br>Communications badge |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Status and feedback information may not be perceivable by people with severe visual impairments.<br>- Area covered by directional response may not be obvious and/or accessible to users with disabilities. |
| Solutions related to accessibility barriers | - Multimodal feedback: provide optional mode with audio indications of status feedback (e.g. low battery or connection established or terminated) as users may have problems understanding feedback related to the status of the microphone if this status information is presented in a modality that the user cannot perceive.<br>- Ensure physical accessibility of area covered by the microphone (e.g. by wheelchairs).<br>- Indicate in an accessible and multimodal way the area covered by the microphone. |
| Cultural issues | None identified |
| Benefit for all users | - Better voice quality in voice conversations.<br>- Increased privacy during calls in public places.<br>- Smaller likelihood of disturbing others by having to speak with a loud voice in order to be understood by the remote interlocutor. |
| Benefits for older people and people with disabilities | - Improves quality of voice communications for people with speech impairments or low voices and for hearing impaired people. |
| Deployment pros | - Ideal for person-to-person voice conversations. |
| Deployment cons | - Not suited for hands-free situations with more than one person at either end. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.2.5: Personal mobile microphones**

| Characteristic | Definition |
|---|---|
| Name | Personal mobile microphones |
| Description | A personal mobile microphone that is worn like a brooch or necklace and that is being used for comfortably communicating with a person or entity (e.g. a smart home) for longer periods of time. The personal mobile microphone can be combined with a personal mobile loudspeaker to function as a communications badge with input/output functionality. |
| Mass market deployment | By 2015 |
| Sub category | Advanced microphones |
| Related technology | Adaptive directive microphone<br>Intelligent (MEMS) microphone<br>Personal mobile loudspeaker<br>Communications badge |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any access features needed) |
| Accessibility barriers | - Status and feedback information may not be perceivable by people with severe visual impairments. |
| Solutions related to accessibility barriers | - Low complexity: provide low-complexity solution with minimum functionality (e.g. make and accept communications request, adjust volume, check battery status).<br>- Multimodal controls: provide information about control location in more than one modality (e.g. visual and tactile). Also allow device operation through different modalities.<br>- Multimodal feedback: provide optional mode with audio indications of status feedback (e.g. low battery or connection established or terminated) as users may have problems understanding feedback related to the status of the microphone if this status information is presented in a modality that the user cannot perceive. |
| Cultural issues | - In some cultures, men will not feel comfortable wearing a device that looks too much like jewellery (e.g. a brooch); therefore a more neutral alternative with a 'technical' look should be offered as well.<br>- In some cultures, users will be sensitive to being overheard unintentionally. |
| Benefit for all users | - Comfortable hands-free communications and voice control. |
| Benefits for older people and people with disabilities | - Easy to use for mobility impaired or low-dexterity users.<br>- Easy to locate (if worn) for visually impaired users. |
| Deployment pros | - Offers location-independent personal audio input functionality for interacting with smart environments (e.g. smart home). |
| Deployment cons | - Requires high battery performance to operate for longer periods. |
| Implementation requirements | - Consider alternative power supplies. |
| Harmonization | None identified |

**Table 6.2.6: Blind source separation**

| Characteristic | Definition |
|---|---|
| Name | Blind source separation |
| Description | Blind source separation (BSS) is a method to de-mix sounds and filter out individual voices from background noise. Conventional BSS algorithms based on matrix-based de-convolution or de-correlation techniques require for each sound a separate microphone. New approaches distinguish one sound from another by estimating the differences in the time of arrival as well as in the amplitude of incoming signals using only two microphones. Thus, if five people in a room are talking simultaneously as well as moving as they speak, that method of BSS is not only able to separate out what each person is saying but also to track the location of each individual. |
| Mass market deployment | By 2015 |
| Sub category | Advanced microphones |
| Related technology | Intelligent (MEMS) microphone<br>Adaptive directive microphone |
| User requirements | 01 Perceive visual information |
| Accessibility barriers | None identified |
| Solutions related to accessibility barriers | None identified |
| Cultural issues | - In some cultures, users will be sensitive to being overheard or tracked unintentionally. |
| Benefit for all users | - Improved voice transmission for hands-free and multiple-speakers-per-site situations. |
| Benefits for older people and people with disabilities | - Improves quality of voice communications for people with speech impairments or low voices and for hearing impaired people. |
| Deployment pros | - Improved quality of voice communications by exchanging microphones, no additional infrastructure (e.g. microphone arrays) required. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.2.7: Communications badge**

| Characteristic | Definition |
|---|---|
| Name | Communications badge |
| Description | A personal wearable communications device that is worn like a brooch or necklace comprising at least a microphone and a loudspeaker and that is being used for comfortably communicating with a person or entity (e.g. a smart home) for longer periods of time. |
| Mass market deployment | By 2015 |
| Sub category | Advanced microphones |
| Related technology | Personal mobile microphone<br>Personal mobile loudspeaker<br>Adaptive directive microphone<br>Intelligent (MEMS) microphone |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>09 Be able to recover from errors<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Status and feedback information may not be perceivable by people with severe visual impairments.<br>- Location and status of controls need to be indicated. |
| Solutions related to accessibility barriers | - Low complexity: provide low-complexity solution with minimum functionality (e.g. make and accept communications request, adjust volume, check battery status).<br>- Multimodal controls: provide information about control location in more than one modality (e.g. visual and tactile). Also allow device operation through different modalities.<br>- Multimodal feedback: provide optional mode with audio indications of status feedback (e.g. low battery or connection established or terminated) as users may have problems understanding feedback related to the status of the microphone if this status information is presented in a modality that the user cannot perceive. |
| Cultural issues | - In some cultures, men will not feel comfortable wearing a device that looks too much like jewellery (e.g. a brooch); therefore a more neutral alternative with a 'technical' look should be offered as well.<br>- In some cultures, users will be sensitive to being overheard unintentionally. |
| Benefit for all users | - Comfortable hands-free communications and voice control. |
| Benefits for older people and people with disabilities | - Easy to use for mobility impaired or low-dexterity users.<br>- Easy to locate (if worn) for visually impaired users. |
| Deployment pros | - Offers location-independent personal audio input and output functionality for interacting with smart environments (e.g. smart home). |
| Deployment cons | - Requires high battery performance to operate for longer periods. |
| Implementation requirements | - Consider alternative power supplies. |
| Harmonization | None identified |

**Table 6.2.8: Intelligent (MEMS) microphones**

| Characteristic | Definition |
|---|---|
| Name | Intelligent (MEMS) microphones |
| Description | Intelligent microphones can be described as micro-electro-mechanical systems (MEMS) with multiple microphones that are constructed on a single silicon wafer using processes originally developed for making ICs. By integrating more than one microphone in one device and by applying smart technologies, the performance of the microphone device can be increased (e.g. turnable directivity, noise reduction). |
| Mass market deployment | After 2015 |
| Sub category | Advanced microphones |
| Related technology | Personal mobile microphone<br>Adaptive directive microphone<br>Smart microphone arrays<br>Optical microphone |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out actions including maintenance and setup<br>07 Be able to complete actions and tasks within the time allowed<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Status and feedback information may not be perceivable by people with severe visual impairments.<br>- Area covered by directional response may not be obvious and/or accessible to users with disabilities. |
| Solutions related to accessibility barriers | - Multimodal feedback: provide optional mode with audio indications of status feedback (e.g. low battery or connection established or terminated) as users may have problems understanding feedback related to the status of the microphone if this status information is presented in a modality that the user cannot perceive.<br>- Ensure physical accessibility of area covered by the microphone (e.g. by wheelchairs).<br>- If necessary, visually indicate the area covered by the microphone. |
| Cultural issues | None identified |
| Benefit for all users | - Improved voice transmission for miniaturized devices.<br>- Improved privacy if used in public places when combined with a motion sensor. |
| Benefits for older people and people with disabilities | - Improves quality of voice communications for people with speech impairments or low voices and for hearing impaired people. |
| Deployment pros | - Improved quality of service in person-to-person voice conversations and voice control.<br>- May improve quality of service (e.g. by facilitating turn taking) in hands-free situations with more than one person at either end. |
| Deployment cons | - If used as a dynamic adaptive directive microphone, the currently-active direction should be visualised. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.2.9: Smart microphone arrays**

| Characteristic | Definition |
|---|---|
| Name | Smart microphone arrays |
| Description | A microphone array consists of any number of microphones operating in parallel. Applications include:<br>(a) systems for extracting voice input from ambient noise (notably telephones, speech recognition systems, hearing aids),<br>(b) surround sound and related technologies,<br>(c) locating objects by sound (acoustic source localization, e.g. military use to locate the source(s) of artillery fire, aircraft location and tracking), and<br>(d) high-fidelity original recordings. Smart microphone arrays can also be used for the voice-control of smart homes. |
| Mass market deployment | After 2015 |
| Sub category | Advanced microphones |
| Related technology | Intelligent (MEMS) microphone<br>Personal mobile microphone |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any access features needed) |
| Accessibility barriers | - Area covered by directional response may not be obvious and/or accessible to users with disabilities. |
| Solutions related to accessibility barriers | - Multimodal feedback: provide optional mode with audio indications of status feedback (e.g. low battery or connection established or terminated) as users may have problems understanding feedback related to the status of the microphone if this status information is presented in a modality that the user cannot perceive.<br>- Ensure physical accessibility of area covered by the microphone (e.g. by wheelchairs).<br>- Unless the areas covered by the array are obvious (e.g. because they are physically delimited), they should be visually indicated. |
| Cultural issues | - In some cultures, users will be sensitive to being overheard unintentionally. |
| Benefit for all users | - Improved quality of service for person/group to person/group communications.<br>- Improved quality of service in outdoor situations.<br>- One possible solution for interaction with smart environments. |
| Benefits for older people and people with disabilities | - Improves quality of voice communications for people with speech impairments or low voices and for hearing impaired people. |
| Deployment pros | - Offers personal audio input functionality for interacting with smart environments (e.g. smart home). |
| Deployment cons | - Probably initially not commercially viable for private environments, as less expensive options (e.g. Personal Mobile Microphone) are available. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.2.10: Auditory UI**

| Characteristic | Definition |
|---|---|
| Name | Auditory UI |
| Description | User interaction entirely audio based (possibly integrated as an optional operational mode, e.g. using a mobile device while driving a car or carrying the device in a bag while wearing Bluetooth headset). |
| Mass market deployment | By 2012 |
| Sub category | Voice-input technologies |
| Related technology | Communications badge<br>Personal mobile microphone |
| User requirements | 02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out actions including maintenance and setup<br>07 Be able to complete actions and tasks within the time allowed<br>08 Avoid unintentional activation of controls<br>09 Be able to recover from errors<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any access features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Deaf people, people with severe hearing impairments, people who are unable to speak and people with speech impairments need alternative interaction modes. |
| Solutions related to accessibility barriers | - Multimodal control: people with speech impairments or those unable to speak will need an alternative method of controlling the user interaction.<br>- Multimodal feedback: deaf or severely hearing impaired people will need an alternative means to receive feedback related to user interaction.<br>- Ensure excellent guidance through available options, expected consequences and results of actions. |
| Cultural issues | - People in some cultures may be concerned about being overheard while talking to a device. |
| Benefit for all users | - Allows interacting with technology when hands are not free or part of the attention is directed to other activities (such as driving). |
| Benefits for older people and people with disabilities | - Easy to use for visually impaired, mobility impaired or low-dexterity users. |
| Deployment pros | - Offers audio input functionality for interacting with networks, devices and smart environments (e.g. smart home).<br>- Can be used for user authentication based on the characteristics of the user's voice. |
| Deployment cons | - None if offered as an alternative to other means of using a device or eService. |
| Implementation requirements | - Fail-safe and easy recovery from the results of falsely understood voice commands.<br>- Implementation of established voice-dialogue design guidelines. |
| Harmonization | - Harmonized voice commands (extension of [i.9]). |

**Table 6.2.11: Speech recognition**

| Characteristic | Definition |
|---|---|
| Name | Speech recognition |
| Description | Speech recognition (also known as automatic speech recognition or computer speech recognition) converts spoken words to text. The term "voice recognition" is sometimes used to refer to recognition systems that need to be trained to a particular speaker - as is the case for some desktop recognition software. Recognizing the speaker can simplify the task of translating speech.<br>Speech recognition is a broader solution which refers to technology that can recognize speech without being targeted at individual speakers - such as a call centre system that can recognize arbitrary voices.<br>Currently, leading Speech Recognition Technologies include Hidden Markov models as well as Dynamic time warping (DTW)-based speech recognition. |
| Mass market deployment | By 2012 |
| Sub category | Voice-input technologies |
| Related technology | Distributed speech recognition<br>Audio-visual speech recognition<br>Intelligent word spotting |
| User requirements | 02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Deaf people, some of whom have mild speech impairments, may need alternative interaction modes.<br>- May present problems for people with speech impairments.<br>- May present problems for people with cognitive impairments who can not remember or understand how to use the system. |
| Solutions related to accessibility barriers | - Ensure functionality even for people with low voices, foreign accents or speech impediments, if necessary by training functions (adapting the system to the individual characteristics of the user's speech).<br>- Provide optional mode with multimodal indications of status feedback (e.g. reading back the text as it has been understood by the machine).<br>- Multimodal control: provide at least one non-speech method of inputting the information that would have been recognized by speech recognition.<br>- Provide users with undo functionality.<br>- Allow for customisation of voice commands.<br>- Provide hints to users on what is the next expected input, if any.<br>- Provide a help function on demand. |
| Cultural issues | - People in some cultures may be more easily frustrated than those of other cultures when the use of a feature leads to unexpected results, which is something likely to result in the context of this technology. |
| Benefit for all users | - Offers an alternative to key or stroke-based text input or the control of small devices. |
| Benefits for older people and people with disabilities | - Offers a natural means of interaction for visually impaired people. |
| Deployment pros | - There are a sheer unlimited number of use cases. |
| Deployment cons | - It will only be taken up if the recognition performance is close to perfect, which it is not yet today. |
| Implementation requirements | - Minimum recognition rate for users that the system has not been trained for. |
| Harmonization | - Harmonized voice commands e.g. for error recovery (extension of [i.9]). |

**Table 6.2.12: Intelligent word spotting**

| Characteristic | Definition |
|---|---|
| Name | Intelligent word spotting |
| Description | Naturally-spoken input for controlling embedded devices is still a challenge. Speech understanding requires profound language models for the particular language in order to allow a semantic extraction of the user's intention. This is especially complicated, if the user forms long and complex sentences or deploys slang or unusual grammatical expressions.<br>Therefore, the intelligent extraction of key words (word spotting) from a spoken flow of words is a more feasible approach. However, on the long term, natural speech understanding might displace the intelligent word spotting technologies. |
| Mass market deployment | By 2015 |
| Sub category | Voice-input technologies |
| Related technology | Speech recognition<br>Distributed speech Recognition<br>Audio-visual speech Recognition |
| User requirements | 02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Deaf people some of whom have mild speech impairments may need alternative interaction modes.<br>- May present problems for people with speech impairments. |
| Solutions related to accessibility barriers | - Ensure functionality even for people with low voices, foreign accents or speech impediments, if necessary by training functions (adapting the system to the individual characteristics of the user's speech).<br>- Multimodal feedback: provide optional mode with multimodal indications of status feedback (e.g. reading back the text as it has been understood by the machine).<br>- Multimodal control: provide at least one non-speech method of inputting the information that would have been recognized by speech recognition. |
| Cultural issues | - People in some cultures may be more easily frustrated than those of other cultures when the use of a feature leads to unexpected results, which is something likely to result in the context of this technology. |
| Benefit for all users | - Offers an alternative to key or stroke-based text input or control of small devices. |
| Benefits for older people and people with disabilities | - Offers a natural means of interaction for visually impaired people. |
| Deployment pros | - There is a potentially large number use cases. |
| Deployment cons | - It will only be taken up if the recognition performance is close to perfect, which it is not yet today. Intelligent word spotting may therefore be a bridge technology until the performance of device-based solutions perform well enough. |
| Implementation requirements | - Minimum recognition rate for users that the system has not been trained for. |
| Harmonization | - Harmonized voice commands e.g. for error recovery (extension of [i.9]). |

**Table 6.2.13: Distributed speech recognition**

| Characteristic | Definition |
|---|---|
| Name | Distributed speech recognition |
| Description | Distributed speech recognition (DSR) separates the low computational power consuming recognizer front-end within the mobile device from a back-end recognizer on the server side that allows complex recognition algorithms and large vocabularies. This combination allows a high performance, device-optimized recognition with low network transmission rates. |
| Mass market deployment | By 2015 |
| Sub category | Voice-input technologies |
| Related technology | Speech Recognition<br>Audio-visual Speech Recognition<br>Intelligent word spotting |
| User requirements | 02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Deaf people some of whom have mild speech impairments may need alternative interaction modes.<br>- May present problems for people with speech impairments. |
| Solutions related to accessibility barriers | - Ensure functionality even for people with low voices, foreign accents or speech impediments, if necessary by training functions (adapting the system to the individual characteristics of the user's speech).<br>- Provide optional mode with audio indications of status feedback (e.g. reading back the text as it has been understood by the machine).<br>- Multimodal control: provide at least one non-speech method of inputting the information that would have been recognized by speech recognition. |
| Cultural issues | - People in some cultures are more concerned about privacy and data protection than those of others. They may not feel comfortable knowing that a commercial enterprise potentially listens into what is being said.<br>- People in some cultures may be more easily frustrated than those of other cultures when the use of a feature leads to unexpected results, which is something likely to result in the context of this technology. |
| Benefit for all users | - Offers an alternative to key or stroke-based text input or device control. |
| Benefits for older people and people with disabilities | - Offers a natural means of interaction for visually impaired people. |
| Deployment pros | - There are a sheer unlimited number of use cases. |
| Deployment cons | - It will only be taken up if the recognition performance is close to perfect, which it is not yet today. Distributed speech recognition may therefore be a bridge technology until the performance of device-based solutions perform well enough.<br>- If the transmission network is not operable the recognition of commanding the device will fail unless an appropriate fallback has been anticipated in design. |
| Implementation requirements | - Minimum recognition rate for users that the system has not been trained for. |
| Harmonization | - Harmonized voice commands e.g. for error recovery (extension of [i.9]). |

**Table 6.2.14: Audio-visual speech recognition**

| Characteristic | Definition |
|---|---|
| Name | Audio-visual speech recognition |
| Description | Audio-visual speech recognition (AVSR) is a technique that uses image-processing capabilities in lip reading to aid speech recognition systems in recognizing non-deterministic phones or supporting the decision among several candidates of equal probability. Each system (lip reading and speech recognition) works separately. Their results are mixed later at the stage of feature fusion. |
| Mass market deployment | After 2015 |
| Sub category | Voice-input technologies |
| Related technology | Speech Recognition<br>Distributed Speech Recognition<br>Intelligent word spotting |
| User requirements | 02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Deaf people some of whom have mild speech impairments may need alternative interaction modes.<br>- May present problems for people with speech impairments. May present problems for people with speech impairments. |
| Solutions related to accessibility barriers | - Ensure functionality even for people with low voices, foreign accents or speech impediments, if necessary by training functions (adapting the system to the individual characteristics of the user's speech).<br>- Provide optional mode with audio indications of status feedback (e.g. reading back the text as it has been understood by the machine).<br>- Multimodal control: provide at least one non-speech method of inputting the information that would have been recognized by speech recognition. |
| Cultural issues | - People in some cultures are more concerned about privacy and data protection than those of others. If the feature is offered as an online service, they may not feel comfortable knowing that a commercial enterprise potentially listens into what is being said.<br>- People in some cultures may be more easily frustrated than those of other cultures when the use of a feature leads to unexpected results, which is something likely to result in the context of this technology. |
| Benefit for all users | - Offers an alternative to key or stroke-based text input or device control. |
| Benefits for older people and people with disabilities | - Offers a natural means of interaction for visually impaired people. |
| Deployment pros | - There is a potentially large number use cases. They are, however, limited by the fact that the speaker's mouth has to be captured by a camera. The feature may be combined with authentication services. |
| Deployment cons | - It will only be taken up if the recognition performance is close to perfect, which it is not yet today. Audio-visual speech recognition may therefore be a bridge technology until the performance of device-based solutions perform well enough. |
| Implementation requirements | - Minimum recognition rate for users that the system has not been trained for. |
| Harmonization | - Harmonized voice commands e.g. for error recovery (extension of [i.9]). |

# 6.3 Kinaesthetic input technologies roadmap

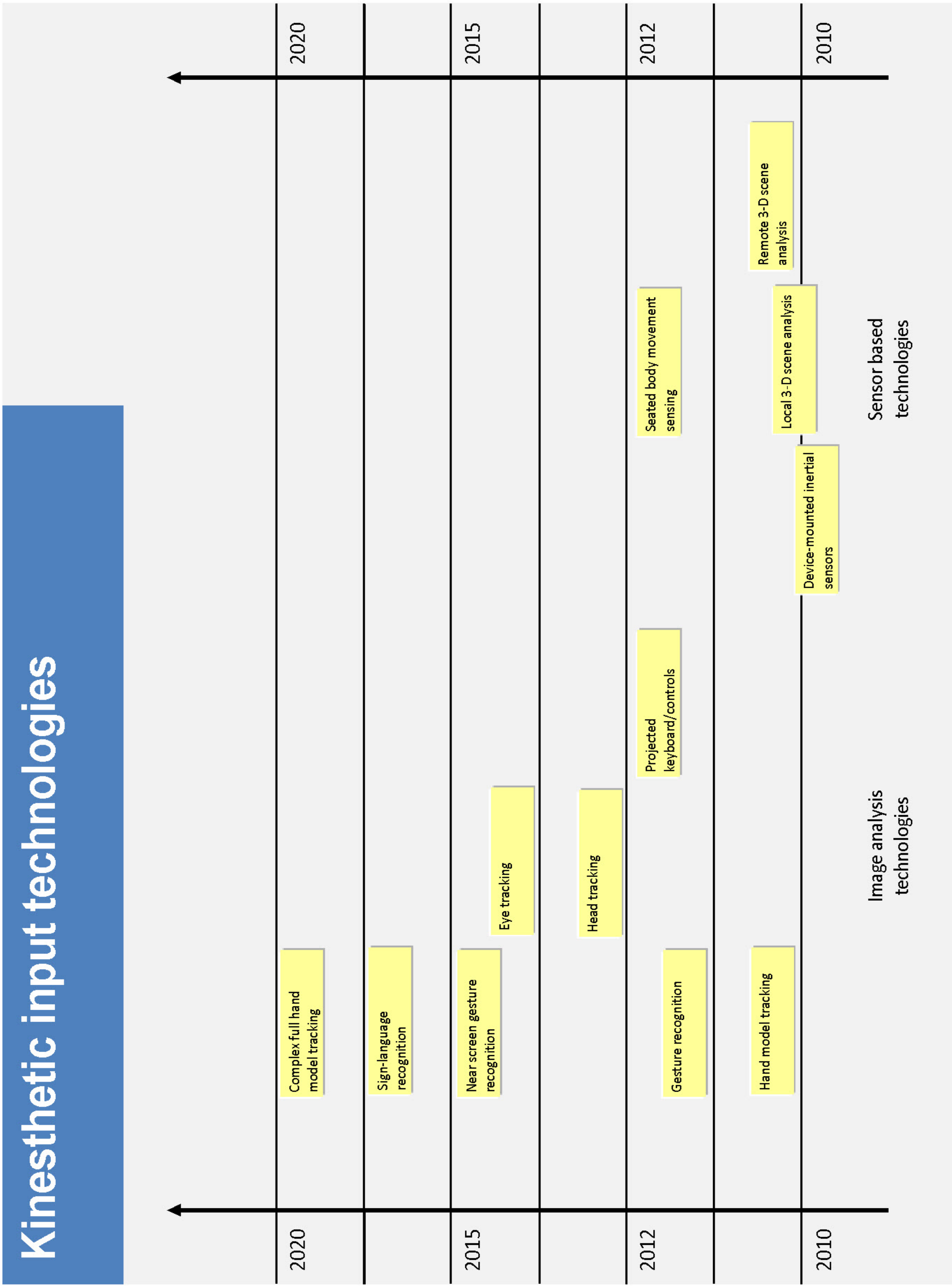


**Figure 6.3.1: Kinaesthetic input technologies roadmap**

The main areas of innovation in the area of kinaesthetic input technologies are gesture recognition, eye tracking and technologies that sense body or limb movements by sensing changes in a projected coded near-infrared field. These technologies will support a range of applications that are more easily supported by "natural" interaction at a distance. Some of these technologies do not require explicit interaction actions from the user to effect interaction with a service.

Key developments in this area are:

- interaction through simple or advanced gestures;
- interaction by gaze only;
- no intrusive user interface;
- the system can monitor the user's behaviour and identify potentially harmful occurrences;
- things "just happen" when wanted.

These technologies have the potential to increase accessibility for people whose impairments make it difficult to use conventional input technologies. In particular, mobility impaired users should benefit from these technologies as in many cases they do not need to move to reach a physical input device. In some cases, people with motor impairments may have problems to make specific movements which are required to communicate with the system. However, these technologies may cause problems for users whose impairments prevent them from receiving feedback that confirms the actions that they have triggered in the service.

- Users with visual impairments may not be able to identify changes in the visual feedback that shows that a movement they have made has resulted in a particular system behaviour.
- Users with hearing impairments may not be able to identify audible feedback that shows that a movement they have made has resulted in a particular system behaviour.

Solutions for these and other accessibility barriers identified for individual or several kinaesthetic input technologies are listed in the tables 6.3.1 to 6.3.12 and include:

- Multimodal indications using more than one sensory modality to indicate the activation (and preferably the identity) of a system function that has been activated.
- A simple and standardized vocabulary of motion-related control gestures and associated behaviours.
- Vocabularies of motion-related control which can be personalised according to user's needs and preferences (e.g. movements the user is able to do).

The following table gives an alphabetical listing of the technologies covered in this clause.

**Table 6.3.1: Overview of kinaesthetic input technologies**

| User interaction technology | Sub category | Table |
|---|---|---|
| Complex full hand model tracking | Image analysis technologies | 6.3.9 |
| Device-mounted inertial sensors | Sensor-based technologies | 6.3.10 |
| Eye tracking | Image analysis technologies | 6.3.6 |
| Gesture recognition | Image analysis technologies | 6.3.3 |
| Hand model tracking | Image analysis technologies | 6.3.2 |
| Head tracking | Image analysis technologies | 6.3.5 |
| Local 3-D scene analysis | Sensor-based technologies | 6.3.11 |
| Near screen gesture recognition | Image analysis technologies | 6.3.7 |
| Projected keyboards/controls | Image analysis technologies | 6.3.4 |
| Remote 3-D scene analysis | Sensor-based technologies | 6.3.12 |
| Seated body movement sensing | Sensor-based technologies | 6.3.13 |
| Sign-language recognition | Image analysis technologies | 6.3.8 |

**Table 6.3.2: Hand model tracking**

| Characteristic | Definition |
|---|---|
| Name | Hand model tracking |
| Description | Tracking of the users hands, without tracking of all fingers. Allowing the user to manipulate virtual objects with hand movements, i.e. up, down, left, right, forward, back, etc. |
| Mass market deployment | By 2012 |
| Sub category | Image analysis technologies |
| Related technology | Gesture recognition<br>Near screen gesture recognition<br>Complex full hand model tracking |
| User requirements | 03 Perceive existence and location of actionable components<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product |
| Accessibility barriers | - Users suffering from hand tremor may not be understood by the system.<br>- Users missing fingers or having hands physically disabled in other ways may not be understood by the system.<br>- Visually impaired users may have difficulty to position their hands in respect to the camera. |
| Solutions related to accessibility barriers | - User limitation compensation: design system to ignore involuntary movement.<br>- User limitation compensation: design system to account for hands not corresponding to the "normal" hand model.<br>- Multimodal feedback: when positioning in front of the camera and also for feedback on actions performed. |
| Cultural issues | - Some users may feel monitored by the camera. |
| Benefit for all users | - This technology could provide a new type of user interface. |
| Benefits for older people and people with disabilities | - The ability to control a system without the precision movements usually required by other input devices (for example keyboards, mice and touch devices). |
| Deployment pros | - Allows for a wide range of new services and products, both business and entertainment related. |
| Deployment cons | - Only works at some distance from the interaction object due to the separation between the camera and the interaction object. |
| Implementation requirements | None identified |
| Harmonization | - Common gesture vocabulary needed. |

**Table 6.3.3: Gesture recognition**

| Characteristic | Definition |
|---|---|
| Name | Gesture recognition |
| Description | The use of hand or body gestures for human computer interaction based on image analysis. |
| Mass market deployment | By 2012 |
| Sub category | Image analysis technologies |
| Related technology | Hand model tracking<br>Near screen gesture recognition<br>Complex full hand model tracking |
| User requirements | 03 Perceive existence and location of actionable components<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product |
| Accessibility barriers | - Users suffering from hand tremor may not be understood by the system.<br>- Users missing fingers or have hands physically disabled in other ways may not be understood by the system.<br>- Visually impaired users may have difficulty to position their hands in respect to the camera.<br>- Users who can not move the way the system expects. |
| Solutions related to accessibility barriers | - User limitation compensation: design system to ignore involuntary movement.<br>- User limitation compensation: design system to account for hands not corresponding to the "normal" hand model.<br>- Multimodal feedback: when positioning in front of the camera and also for feedback on gestures performed.<br>- Allow for personalisation of the vocabulary of movements, according to user needs and preferences. |
| Cultural issues | - Some gestures are inappropriate in different cultures.<br>- Some users may feel monitored by the camera. |
| Benefit for all users | - Provides a more varied interface. |
| Benefits for older people and people with disabilities | - Possibly easier and quicker interaction for blind and deaf-blind users. |
| Deployment pros | - New products making use of this type of interface could be almost any type of electronic gadget that is now operated by touch or a button. |
| Deployment cons | - Only works at some distance from the interaction object due to the separation between the camera and the interaction object. |
| Implementation requirements | None identified |
| Harmonization | - Common gesture vocabulary is needed. |

**Table 6.3.4: Projected keyboards/controls**

| Characteristic | Definition |
|---|---|
| Name | Projected keyboards/controls |
| Description | Controls or keyboard projected on a surface where interaction with these components is interpreted by a camera. |
| Mass market deployment | By 2012 |
| Sub category | Image analysis technologies |
| Related technology | None identified |
| User requirements | 03 Perceive existence and location of actionable components<br>08 Avoid unintentional activation of controls |
| Accessibility barriers | - Hard to use for people with motoric disabilities and tremors.<br>- Visually impaired users could have problems perceiving actionable components. |
| Solutions related to accessibility barriers | - User limitation compensation: design system to ignore involuntary movement.<br>- Multimodal feedback: provide audio feedback on positioning over control and control activation. |
| Cultural issues | None identified |
| Benefit for all users | - An intuitive and possibly lightweight user interface solution. |
| Benefits for older people and people with disabilities | - User interfaces can be easily customised compared to fixed physical interfaces. |
| Deployment pros | - Could result in more compact ICT devices. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.3.5: Head tracking**

| Characteristic | Definition |
|---|---|
| Name | Head tracking |
| Description | Tracking of the user's head movement in all directions can be used to, for example, create the feeling of looking through a window on a normal 2D screen. Objects could also be scaled in relation to the users distance from the screen. This could also be done with various sensors instead of or as well as cameras. |
| Mass market deployment | By 2012 |
| Sub category | Image analysis technologies |
| Related technology | Eye tracking |
| User requirements | 03 Perceive existence and location of actionable components<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product |
| Accessibility barriers | - Users with involuntary head movement may cause unintended activation of controls.<br>- Visually impaired users may have difficulty to position themselves in respect to the camera, and also to perform movement-eye co-ordination. |
| Solutions related to accessibility barriers | - User limitation compensation: design the system to ignore involuntary head movement.<br>- Multimodal feedback: when positioning in front of the camera and for every step in user-system interaction. |
| Cultural issues | - Some users may feel monitored by the camera. |
| Benefit for all users | - This technology could provide a better user experience for all users in new innovative interfaces or games. |
| Benefits for older people and people with disabilities | - The ability to control an interface by head movement only. |
| Deployment pros | - Will allow more immersive software. |
| Deployment cons | - Only works for one user at a time. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.3.6: Eye tracking**

| Characteristic | Definition |
|---|---|
| Name | Eye tracking |
| Description | The use of gaze to control a user interface, usually by controlling the mouse cursor. |
| Mass market deployment | By 2015 |
| Sub category | Image analysis technologies |
| Related technology | Head tracking |
| User requirements | 03 Perceive existence and location of actionable components<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product |
| Accessibility barriers | - Users suffering from involuntary head or eye movements could encounter difficulties when using this technology.<br>- Visually impaired users may have difficulty in positioning themselves properly, and also to perform movement-eye co-ordination. |
| Solutions related to accessibility barriers | - User limitation compensation: design the system to ignore involuntary movement.<br>- Multimodal feedback: when positioning in front of the camera and for every step in user-system interaction. |
| Cultural issues | - Some users may feel monitored by the eye-tracking cameras. |
| Benefit for all users | - The possibility to interact while not being able to use ones hands. |
| Benefits for older people and people with disabilities | - For those not able to use their hands this is a good modality. |
| Deployment pros | - Allows for many new products where gaze can be used, for example in cars and in advertising. |
| Deployment cons | - The setting-up and maintenance of the exact positioning/calibration of the head/eye-position in relation to the camera can be critical for some forms of eye-tracking technologies. |
| Implementation requirements | - Lower processing power requirements. |
| Harmonization | None identified |

**Table 6.3.7: Near screen gesture recognition**

| Characteristic | Definition |
|---|---|
| Name | Near screen gesture recognition |
| Description | The use of hand or body gestures for human computer interaction based on image analysis in close proximity to the screen. |
| Mass market deployment | By 2015 |
| Sub category | Image analysis technologies |
| Related technology | Hand model tracking<br>Gesture recognition<br>Complex full hand model tracking |
| User requirements | 03 Perceive existence and location of actionable components<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product |
| Accessibility barriers | - Users suffering from hand tremor may not be understood by the system.<br>- Users missing fingers or having hands physically disabled in other ways may not be understood by the system.<br>- Visually impaired users may have difficulty to position their hands in respect to the camera.<br>- Users may not be able to move the way the system expects. |
| Solutions related to accessibility barriers | - User limitation compensation: design system to ignore involuntary movement.<br>- User limitation compensation: design system to account for hands not corresponding to the "normal" hand model.<br>- Multimodal feedback: when positioning in front of the camera and also for feedback on gestures performed.<br>- Allow for personalisation of the vocabulary of movements, according to user needs and preferences. |
| Cultural issues | - Some gestures are inappropriate in different cultures. |
| Benefit for all users | - More varied interface. |
| Benefits for older people and people with disabilities | - Possibly easier and quicker interaction for blind and deaf-blind users. |
| Deployment pros | - A touchless gesture interface would allow for more versatile and hygienic products to be developed. |
| Deployment cons | None identified |
| Implementation requirements | - Screen technology needs to mature before this technology can be launched. |
| Harmonization | - Common gesture vocabulary is needed. |

**Table 6.3.8: Sign-language recognition**

| Characteristic | Definition |
|---|---|
| Name | Sign-language recognition |
| Description | The automatic real-time interpretation of sign language into text or speech. |
| Mass market deployment | After 2015 |
| Sub category | Image analysis technologies |
| Related technology | Gesture recognition<br>Complex full hand model tracking |
| User requirements | 03 Perceive existence and location of actionable components<br>12 Be able to efficiently operate product |
| Accessibility barriers | - Users suffering from hand tremor may not be understood by the system.<br>- Users missing fingers or having hands physically disabled in other ways may not be understood by the system.<br>- Visually impaired users may have difficulty to position their hands in respect to the camera. |
| Solutions related to accessibility barriers | - User limitation compensation: design system to ignore involuntary movement.<br>- User limitation compensation: design system to account for hands not corresponding to the "normal" hand model.<br>- Multimodal feedback: when positioning in front of the camera.<br>- Establish QoS criteria for sign language interpretation. |
| Cultural issues | - Sign language users may be reluctant to communicate with an interpreter who is not a human.<br>- Many different sign languages exist worldwide and systems may need to be able to adapt to these differences. |
| Benefit for all users | - Easier communication for/with the deaf and other sign language users. |
| Benefits for older people and people with disabilities | - Deaf people need not rely on a human interpreter for telecommunications. |
| Deployment pros | - Potential for online services as well as locally run services. |
| Deployment cons | - Initial services may provide low quality compared to human interpretation and users may be forced into using these.<br>- The utility of systems will be limited by the number of different sign languages that can be recognized.<br>- The utility of systems will be limited according to the variability in ways of forming signs that can be accommodated.<br>- Sign language transliteration to text/speech is very complex. |
| Implementation requirements | - Many complex tasks need to be performed in parallel to achieve proper sign language recognition (linguistics analysis, facial expressions, lip movement, hand and finger movement). Neither of these parts is mature at this time. |
| Harmonization | - QoS criteria. |

**Table 6.3.9: Complex full hand model tracking**

| Characteristic | Definition |
|---|---|
| Name | Complex full hand model tracking |
| Description | Real-time tracking of the full movements of the user's hands and all its parts. Allowing the user to manipulate virtual objects with ordinary hand movements, i.e. gripping, lifting, etc. Current prototypes use a colour-coded glove. |
| Mass market deployment | After 2015 |
| Sub category | Image analysis technologies |
| Related technology | Hand model tracking<br>Gesture recognition<br>Near screen gesture recognition<br>Sign-language recognition |
| User requirements | 03 Perceive existence and location of actionable components<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product |
| Accessibility barriers | - Users suffering from hand tremor may not be understood by the system.<br>- Users missing fingers or having hands physically disabled in other ways may not be understood by the system.<br>- Visually impaired and blind users may experience problems in perceiving the virtual hand and identifying where to position their hands in respect to the camera. |
| Solutions related to accessibility barriers | - User limitation compensation: design system to ignore involuntary movement.<br>- User limitation compensation: design system to account for hands not corresponding to the "normal" hand model.<br>- Multimodal feedback: when positioning in front of the camera. |
| Cultural issues | - Some users may feel monitored by the camera. |
| Benefit for all users | - This technology could provide the ability to interact with on-screen objects in a natural way that feels more direct than using pointing devices. |
| Benefits for older people and people with disabilities | - Could result in new services such as sign-language recognition. |
| Deployment pros | - Would allow for products with a very intuitive interface for use in 3D environments, for example an interface to manipulate 3D models. |
| Deployment cons | None identified |
| Implementation requirements | - Gloves have to be more inconspicuous for main-stream use. |
| Harmonization | None identified |

**Table 6.3.10: Device-mounted inertial sensors**

| Characteristic | Definition |
|---|---|
| Name | Device-mounted inertial sensors |
| Description | There are a large range of technologies that enable many types of change in the position of a device to be detected. These can range from very simple tilt sensing and angular rate sensing technologies, to sophisticated multi-axis accelerometer and gyroscope-based technologies that enable the sensing of orientation and magnitude as well as detecting the direction of the acceleration of the device to be measured in multiple axes. The recent emergence of small inexpensive MEMS and piezoelectric-based gyroscopes and accelerometers permits very fast and precise measurements about the positioning and movement of small handheld devices to be determined. |
| Mass market deployment | By 2012 |
| Sub category | Sensor-based technologies |
| Related technology | None identified |
| User requirements | 04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Blind users may be unaware that they have accidentally operated a motion-based function as they will not be able to see the on-screen result of the operation. |
| Solutions related to accessibility barriers | - Equivalent simultaneous control: there should be a mechanism to override any and all motion-based function activations and an alternative mechanism for activating the function(s) should be provided.<br>- Barrier-free user education: help on the alternate activation mechanism should be easily available at the time that the motion sensing activation of the function is disabled.<br>- Multimodal feedback: audible, visual and tactile feedback that a motion activated function operation has occurred should be available. |
| Cultural issues | None identified |
| Benefit for all users | - The use of these technologies enable many functions (e.g. screen orientation, rapid operation of frequently required function) to be controlled by simple movements of a device.<br>- In many instances the movement of the device and the resultant operation in the user interface can be very intuitively linked (e.g. rotating the device rotates the screen orientation). |
| Benefit for older people and people with disabilities: | - Visually impaired users will not need to locate on-screen controls in order to perform a movement-based operation.<br>- People with hand tremor will not have to position their fingers over often small on-screen or physical controls in order to activate functions. |
| Deployment pros | - New functions can be added to applications without increasing the on-screen or keyboard clutter by having to add additional controls. |
| Deployment cons | - There is a high risk that natural movements of the device when, for instance, adjusting seating position, can cause a motion-related function to be accidentally operated. |
| Implementation requirements | None Identified. |
| Harmonization | - It would be beneficial if there was a standardized vocabulary of motion-related control gestures and associated behaviours. |

**Table 6.3.11: Local 3-D scene analysis**

| Characteristic | Definition |
| --- | --- |
| Name | Local 3-D scene analysis |
| Description | Technologies that allow a 3-D scene to be analyzed by sensors incorporated in a device held or worn by the user. These technologies track the movement and position of a user or a part of the user (e.g. hand) within the local environment. These technologies may be combined with location sensing technologies to identify the absolute position of the user.<br><br>One form of this technology uses a sensor in a worn or carried device to sense multiple infra-red light sources in order to determine the position of a user or a part of the user (e.g. a hand) in relation to those sources.<br><br>When this technology is used to portray avatars that replicate the movements of the people in the room, people are able to remotely interact with on-screen controls and virtual environments wherever they are in the room. |
| Mass market deployment | By 2012 |
| Sub category | Sensor-based technologies |
| Related technology | Remote 3-D scene analysis<br>Gesture recognition<br>Hand model tracking<br>Locally-sensed location |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Where visual feedback is used to confirm the result of the user's movements, blind users will be unable to identify the success or failure of the actions that they intended to perform. |
| Solutions related to accessibility barriers | - Sustained effort minimization: use of such technologies for fine-grained control should be restricted to situations where short-term intensive usage is envisaged (as in the playing of computer games).<br>- Multimodal feedback: audible and tactile feedback should be used in addition to visual feedback in order to confirm the activation of functionality. |
| Cultural issues | None identified |
| Benefit for all users | - Where a body-worn or carried sensor is utilised to enable the sensing of the movement of the person's whole body, the use of this technology would allow anyone to interact with a system without having to manipulate special user interaction components.<br>- Where a carried sensor is used to enable sensing of the movement of a person's hand, control can be effected by means of simple pointing and gestures without having to master the use of a special control device. |
| Benefits for older people and people with disabilities | - Mobility impaired users will not need to position themselves relative to physically located control interfaces |
| Deployment pros | - The technology to support this form of interaction will be available at consumer-friendly prices (due to the likely high demand for this technology in the mass market games domain). |
| Deployment cons | - As the sensing of the user is performed by the carried or worn device, fine control of positioning of movements is only possible if the senor is mounted in a hand-held device - thereby necessitating the device to be always carried in the hand to be useful.<br>- If a body-worn sensor is used, the system will fail if the user forgets to wear, or chooses not to wear, the sensor. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.3.12: Remote 3-D scene analysis**

| Characteristic | Definition |
| --- | --- |
| Name | Remote 3-D scene analysis |
| Description | Those technologies that allow a 3-D scene to be analyzed by sensors remotely from the user to track either whole-body movement of the user and/or the movement of the whole range of the user's body parts. These technologies can sometimes be combined with recognition technologies to identify the user.<br><br>One method uses a coded near-IR radiation to illuminate a scene and an image sensor reads the coded light back from the scene. This received information is processed to produce a depth image of the scene. The solution is immune to ambient light. This analysis of a depth image allows the system to identify the spatial location and movement of people and body parts in a way that supports the identification of gesture interaction from more than one person.<br><br>When this technology is used to portray avatars that replicate the movements of the people in the room, people are able to remotely interact with on-screen controls and virtual environments wherever they are in the room. |
| Mass market deployment | By 2012 |
| Sub category | Sensor-based kinaesthetic input |
| Related technology | Local 3-D scene analysis<br>Gesture recognition<br>Hand model tracking<br>Remotely sensed location |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Blind users, who are unable to see visual feedback, may be unaware that they are being sensed and that they are interacting with a system. |
| Solutions related to accessibility barriers | - Where remote 3-D scene analysis is performed, users should be made aware that such sensing is taking place. |
| Cultural issues | None identified |
| Benefit for all users | - The use of this technology would allow anyone to interact with a system without the use of special user interaction components.<br>- This technology supports multiple people simultaneously remotely interacting with a service. |
| Benefits for older people and people with disabilities | - Mobility impaired users will not need to position themselves relative to physically located control interfaces.<br>- Easy to use for mobility impaired or low-dexterity users. |
| Deployment pros | - The technology to support this form of interaction will be available at consumer-friendly prices (due to the likely high demand for this technology in the mass market games domain). |
| Deployment cons | - As the sensing of the user is performed remotely, information about the user is also gathered and held remotely and may constitute an invasion of privacy. |
| Implementation requirements | None identified |
| Harmonization | - There is a need for standards related to good practice in handling the personal privacy issues associated with remote sensing technologies. |

**Table 6.3.13: Seated body movement sensing**

| Characteristic | Definition |
|---|---|
| Name | Seated body movement sensing |
| Description | Any technology that allows changes in the body position of a seated person to be detected and analyzed. There are a range of technologies such as capacitive sensing of movements of the body within the local surrounding structure (e.g. car body), surface seat foil sensors that use porous electret film and other piezoelectric and "quasi-piezoelectric" membranes built into seats.<br><br>Such technologies are expected to be increasingly used in automobile applications as part of a set of systems that can detect unexpected changes of body position (e.g. slumping) that may indicate that the subject is becoming drowsy. |
| Mass market deployment | By 2015 |
| Sub category | Sensor-based technologies |
| Related technology | Head tracking |
| User requirements | 05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - The system could be confused by users who exhibit involuntary movements and misinterpret the significance of such movements. |
| Solutions related to accessibility barriers | - There may need to be a calibration process that sets an appropriate threshold for setting drowsiness alarms. Either the information about drowsiness should only be used locally within the vehicle to generate alarms or the user should be clearly informed how the drowsiness detection data is being transmitted to third parties. |
| Cultural issues | None identified |
| Benefit for all users | - The user could be protected from the potentially fatal effects of falling asleep whilst driving. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - The costs of fitting such technologies could be minimised if incorporated as standard equipment across all vehicles. |
| Deployment cons | - There is a risk that there will be many false inferences about the state of drowsiness which could create too many annoying and distracting warnings.<br>- There could be concerns about whether information that the driver is driving whilst in a drowsy state is made available to third parties (e.g. insurance companies and the police). |
| Implementation requirements | None identified |
| Harmonization | - There is a need for standards related to good practice in handling the personal privacy issues associated with remote sensing technologies. |

## 6.4 Presence/location/proximity-based input technologies roadmap

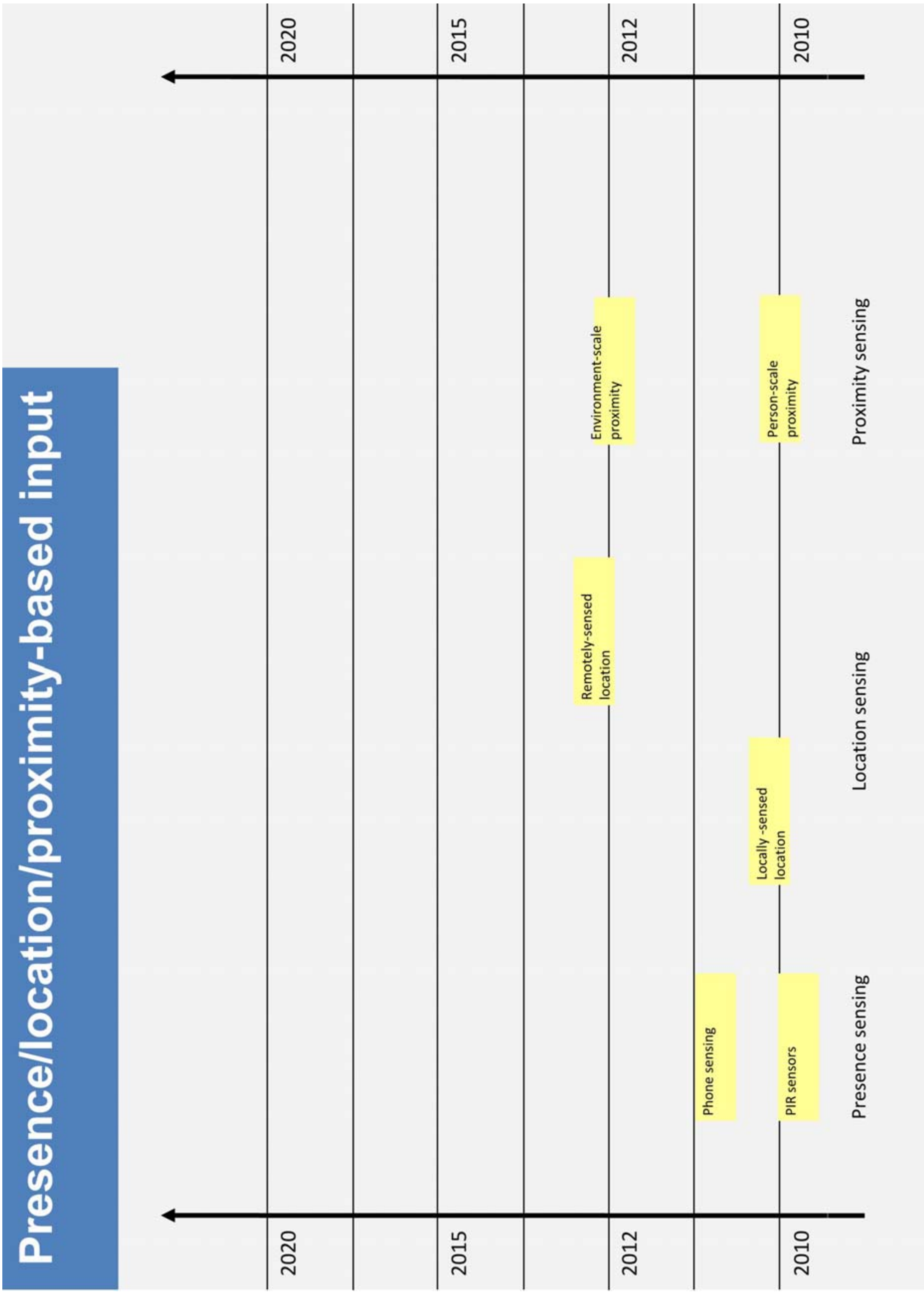


**Figure 6.4.1: Presence/location/proximity-based input technologies roadmap**

Sensing is one of the technologies that will influence many systems in the future as the systems try to infer more about the usage context. The main area of innovation in presence, location and proximity sensing is:

- more techniques for sensing presence, location and proximity will be widely deployed.

These technologies allow interaction with ICT devices and services without a "user interface", or with a user interface that is only provided in order to make interaction more explicit.

Key developments are:

- no intrusive user interface;
- things "just happen" when wanted i.e. system behaviour is automated;
- avoidance of unintended actions that may occur if presence, location or proximity are incorrectly interpreted by the system.

These technologies have the potential to increase accessibility, for example:

- users with visual impairments do not need to find user interface controls;
- those with impairments may not need to understand or manually operate an interface to a device or service.

The technologies may cause problems for users with impairments:

- feedback related to sensing success/failure may not be detected if presented in the wrong modality:
  - visually impaired users may be unaware that they are being sensed if only visual feedback of sensing is employed;
  - hearing impaired users maybe unaware that they are being sensed if only audible feedback is employed.

A common solution is:

- feedback that presence and mood/activity sensing is taking place should be multimodal.

Technologies that are working together with, or are completely reliant upon, such sensing components might need to be designed with a strategy to handle the potential failure of the sensing components. The stability and predictability engendered by such a strategy should enhance feelings of comfort and trust and even provide, where found necessary, a fail-safe or fail-soft mechanism.

People considering the use of presence/location/proximity-based input technologies in ICT devices and services can find additional useful insights and information in the following sources: [Stephanidis, 2009], [Stephanidis, 2007] (general accessibility issues related to presence, location and proximity-based input technologies); [Campbell et al., 2008] (presence sensing); [Hightower, Vakili, Borriello, & Want, 2001], [Callaghan, Gormley, McBride, Harkin, & McGinnity, 2006] (location sensing).

The following table gives an alphabetical listing of the technologies covered in this clause.

**Table 6.4.1: Overview of presence/location/proximity-based input technologies**

| User interaction technology | Sub category | Table |
|---|---|---|
| Environment-scale proximity | Proximity sensing | 6.4.7 |
| Locally-sensed location | Location sensing | 6.4.4 |
| Person-scale proximity | Proximity sensing | 6.4.6 |
| PIR sensing | Presence sensing | 6.4.2 |
| Remotely-sensed location | Location sensing | 6.4.5 |
| RF device sensing | Presence sensing | 6.4.3 |

**Table 6.4.2: PIR sensing**

| Characteristic | Definition |
|---|---|
| Name | PIR sensing |
| Description | The presence of people in an environment is detected by Passive Infrared (PIR) sensors detecting the infrared (IR) radiation emanating from people in their field of view. |
| Mass market deployment | By 2012 |
| Sub category | Presence sensing |
| Related technology | RF sensing |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | None identified |
| Solutions related to accessibility barriers | None identified |
| Cultural issues | - In some cultures or settings it might be inappropriate to sense the presence/activity of people. |
| Benefit for all users | - Features of a service can be activated automatically on entry into the operational range of the PIR sensor. Examples in a Smart Home environment might include switching on (and off) lighting, heating, air-conditioning when one or more people is in a room.<br>- People unfamiliar with an environment such as a public building would not be required to find/identify the controls needed to activate the required functionality. |
| Benefits for older people and people with disabilities | - Any person with a degree of motor impairment would be relieved from the effort of manually activating the required functionality via a switch or more complex user interface.<br>- Blind users would not need to locate the controls needed to activate a beneficial functionality.<br>- Users with cognitive impairments would not need to understand any operational procedure to activate the service function controlled by the PIR sensing. |
| Deployment pros | PIR sensors are readily available in 2010. |
| Deployment cons | - The cost of equipping large areas with multiple PIR sensors.<br>- The negative effects on the service that is receiving input from the sensors if there are false activations caused by the detection of non-humans (e.g. cats and dogs).<br>- Some people might perceive a privacy intrusion just because they have been sensed, even though the technology does not allow the sensed person to be identified. |
| Implementation requirements | - A combination of careful sighting of sensors and sophisticated sensor information interpretation software is required to ensure that unintended activation by non-humans (e.g. cats and dogs) is avoided. |
| Harmonization | None identified |

**Table 6.4.3: RF device sensing**

| Characteristic | Definition |
|---|---|
| Name | RF device sensing |
| Description | The presence (but not identity) of one or more people in an environment is detected by detecting Wi-Fi and/or Bluetooth signals transmitted by those people's mobile devices (e.g. phones or laptops). |
| Mass market deployment | By 2012 |
| Sub category | Presence sensing |
| Related technology | PIR sensing. |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - The technology effectively creates a new accessibility barrier against people who are not carrying an RF enabled mobile device, or who do not have the Wi-Fi or Bluetooth functionality of the device activated. |
| Solutions related to accessibility barriers | - Alternative means of providing the same kind of functions or services need to be accessible for people who are not carrying an RF enabled mobile device or have it switched off. |
| Cultural issues | - In some cultures or settings it might be inappropriate to sense the presence/activity of people. |
| Benefit for all users | - Features of a service can be activated automatically on entry into the operational range of the RF device sensing. Examples in a Smart Home environment might include switching on (and off) lighting, heating, air-conditioning when one or more people is in a room.<br>- People unfamiliar with an environment such as a public building would not be required to find/identify the controls needed to activate the required functionality. |
| Benefits for older people and people with disabilities | - Any person with a degree of motor impairment would be relieved from the effort of manually activating the required functionality via a switch or more complex user interface.<br>- Blind users would not need to locate the controls needed to activate a beneficial functionality.<br>- Users with cognitive impairments would not need to understand any operational procedure to activate the service function controlled by the RF device sensing. |
| Deployment pros | - The detection of RF enabled mobile devices can give absolute identifications of whether a phone or other device (with Wi-Fi or Bluetooth activated) is within the range of the detection system or not (and the number of discrete phones detected) and is less prone to detecting incorrect targets that systems such as PIR sensors. |
| Deployment cons | - The negative effects on the service that is receiving input from the sensors if there are false activations within a service caused by the detection of other RF enabled devices outside the range envisaged by the designer of the service.<br>- Some people might perceive a privacy intrusion just because they have been sensed, even though the technology should not provide the identity of the person using the sensed RF enabled device.<br>- Those people not carrying a RF enabled mobile device, or who do not have either Wi-Fi or Bluetooth activated, will not be detected and will not benefit from the service features activated by the detection of the device.<br>- This technology needs to be sensitive to the spatial distribution of the signal detected; if such sensing "cells" are too small or too wide it may result in imprecise measurements/signals of presence or absence. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.4.4: Locally-sensed location**

| Characteristic | Definition |
|---|---|
| Name | Locally-sensed location |
| Description | Locally sensed location is possible where there are passive location system technologies employed. In such systems, the location system sends location-based information that is processed by a sensor carried by the user (usually in a portable device such as a smart phone) and the processing calculates the user's location. The service can then perform an action based upon the user's location. The location computed may be absolute, or relative to the local environment. Examples are GPS for external location and wireless beacon-based systems. |
| Mass market deployment | By 2012 |
| Sub category | Location sensing |
| Related technology | Remotely-sensed location |
| User requirements | 04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls |
| Accessibility barriers | - Users may be unaware that the service has performed an action based on the user's location if the feedback of that action is presented in a modality that the user cannot detect. |
| Solutions related to accessibility barriers | - Multimodal feedback: in environments in which location sensing is taking place, the user should be made aware through multiple alternate channels. Fixed visual notification, messages on the user's device screen, audible notification from the user's device. |
| Cultural issues | - In some cultures or settings it might be inappropriate to sense the presence/activity of people. |
| Benefit for all users | - These technologies can allow the user's location to be calculated and presented to the user with no, or very little, user interaction.<br>- The user's location can be used to activate functionality within the user's device(s) or services (e.g. configure location context dependent functionality). |
| Benefits for older people and people with disabilities | - Knowledge of location is valuable information that blind users often find difficult to determine. These technologies allow this information to be conveyed to the user in ways compatible with their ability to sense and comprehend the data. |
| Deployment pros | - The technology for location determination is already built into many devices carried by people (e.g. GPS modules and Wi-Fi router based location sensing). |
| Deployment cons | - These technologies can be expensive compared to remotely-sensed location systems.<br>- If the location information is required by some external service it will be necessary to transmit the location information to the service.<br>- All systems will fail to provide the required accurate position information if the signal from the sources are blocked, interfered with or too weak. |
| Implementation requirements | - Where continuous availability location information is of importance (e.g. in navigational applications) an alternative form of computing location should be available for use when the positioning signals are (temporarily) unavailable or insufficient to provide accurate location. An example of such a backup system is the availability of a system that can compute distance and direction of travel since the last available positioning signal was received. |
| Harmonization | None identified |

**Table 6.4.5: Remotely-sensed location**

| Characteristic | Definition |
|---|---|
| Name | Remotely-sensed location |
| Description | Remotely-sensed location is possible where there are active location system technologies employed. In such systems, the location system senses the location of an active device (or signal reflecting device) carried by the user (usually in a portable device such as a smart phone). The positioning system calculates the position of the user and uses this information to invoke certain functions within a service. |
| Mass market deployment | By 2015 |
| Sub category | Location sensing |
| Related technology | Locally-sensed location |
| User requirements | 05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Users may be unaware that the service has performed an action based on the user's location if the feedback of that action is presented in a modality that the user cannot detect. |
| Solutions related to accessibility barriers | - Multimodal feedback: in environments in which location sensing is taking place, the user should be made aware through multiple alternate channels. Fixed visual notification, messages on the user's device screen, audible notification from the user's device. |
| Cultural issues | - In some cultures or settings it might be inappropriate to sense the presence/activity of people. |
| Benefit for all users | - The use of this technology can allow an eService to respond to the user's current location related context without any interface-specific user interaction. |
| Benefits for older people and people with disabilities | - Mobility impaired users will not need to position themselves relative to physically located control interfaces<br>- This technology does not require the use of any of the human senses to activate the necessary functions and hence can be used by a wide range of users with sensory impairments |
| Deployment pros | None identified |
| Deployment cons | - By default, users will be unaware of when and if their current location is being sensed.<br>- Both of the above represent significant privacy issues. |
| Implementation requirements | - The user's device should be capable of providing feedback to the user of the fact that they are being sensed. |
| Harmonization | None identified |

**Table 6.4.6: Person-scale proximity**

| Characteristic | Definition |
|---|---|
| Name | Person-scale proximity |
| Description | These technologies detect when a users device, a point on the user's device or a surface on the user's device is in close proximity to the user's body. |
| Mass market deployment | By 2012 |
| Sub category | Proximity sensing |
| Related technology | Environment-scale proximity |
| User requirements | 04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - This technology will be ineffective in situations where a person's disability requires them to have their device strapped to their body. |
| Solutions related to accessibility barriers | - User limitation compensation: an alternative means of activating all of the functions associated with proximity detection should be provided. |
| Cultural issues | - In some cultures or settings it might be inappropriate to sense the presence/activity of people. |
| Benefit for all users | - Actions that are relevant when the device is in close proximity to the user's body (e.g. de-activation of touch-screen functions when a screen is placed to the user's face whilst making a phone call or the deactivation of a ringing signal when the device is picked up) can be initiated without the need for the user to explicitly activate the functions associated with the proximity detection. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - No need to provide user interface support related to body proximity related functions. |
| Deployment cons | None identified |
| Implementation requirements | - The sensitivity of the detection mechanism should be very precisely adjusted (and/or user adjustable) to ensure that the automatic functionality is triggered when required but not triggered at inappropriate times. |
| Harmonization | None identified |

**Table 6.4.7: Environment-scale proximity**

| Characteristic | Definition |
|---|---|
| Name | Environment-scale proximity |
| Description | Technologies that allow an interactive object in the environment to detect the close presence of a person in order to activate some functionality of the interactive object. The interactive object can be a public display screen device. |
| Mass market deployment | By 2015 |
| Sub category | Proximity sensing |
| Related technology | Person-scale proximity |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Users may be unaware that the service has performed an action based on the user's location if the feedback of that action is presented in a modality that the user cannot detect. |
| Solutions related to accessibility barriers | - Multimodal feedback: the user should be made aware that they have been detected and the nature of the resultant action taken through multiple alternate channels. Both visual notifications on any screen present on the interactive object and an audible indication from the interactive object should be provided. |
| Cultural issues | - In some cultures or settings it might be inappropriate to sense the presence/activity of people.<br>- Feedback related to being sensed by the interactive technology needs to respect the sensitivity to personal privacy issues that is common in the region in which the technology is deployed. |
| Benefit for all users | - The user can benefit from any service provided activated via the interactive object without the need to be aware that the service exists or the need to explicitly request it. |
| Benefits for older people and people with disabilities | - Blind users can potentially benefit from the service provided via activation of the interactive object without needing to see any notification that the service can be provided. |
| Deployment pros | None identified |
| Deployment cons | None identified |
| Implementation requirements | - The nature of any feedback to the user should be provided in a way that takes into account any personal privacy issues that could occur if the interactive object is in a very public space. |
| Harmonization | None identified |

## 6.5 Recognition/mood/activity-based input technologies roadmap

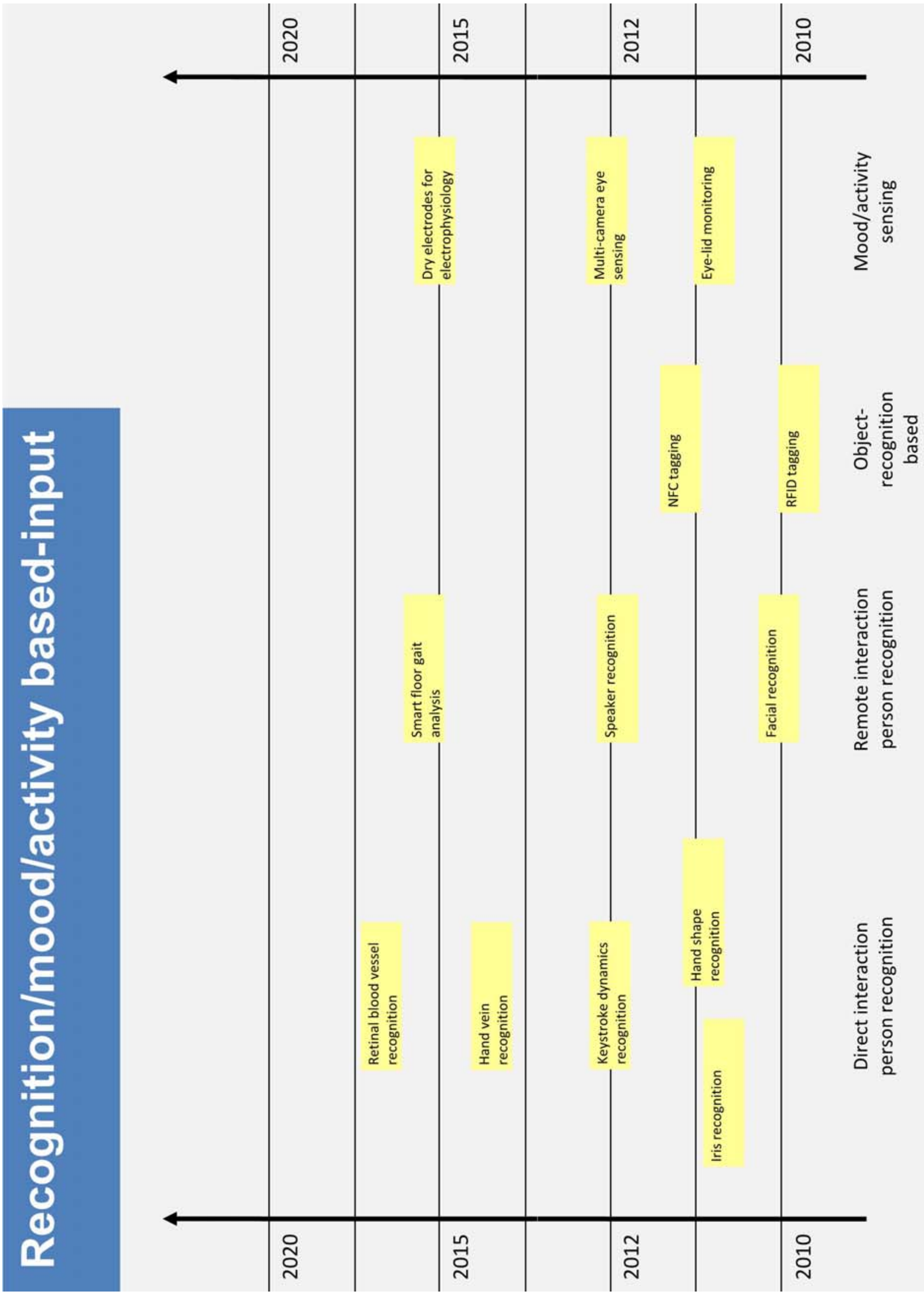


**Figure 6.5.1: Recognition/mood/activity-based input technologies roadmap**

The main areas of innovation in recognition-based user interaction are:

- its use in everyday user interactions with ICT devices and services;
- user interaction based on the identification of objects owned or used by the user.

These technologies allow easier deployment of services where security is important to users.

Key developments are:

- more biometric identification techniques becoming cost effective in mainstream products and services;
- using multiple recognition techniques, (in parallel) to provide more reliable recognition, becoming cost-effective in mainstream products and service.

These technologies have the potential to increase accessibility because:

- biometric techniques could replace authentication user interfaces that currently may create challenges for users with impairments e.g. looking for letters hidden in complex images is a task that those with impaired vision sometimes cannot successfully complete.

They may cause problems for users with impairments. Problems include:

- users with visual impairments may be unaware that they are being identified;
- "false positives" or signal-detection misses might be attributed to an incorrect identification when, in reality, this may be due to an undetected technology failure;
- feedback related to sensing success/failure may not be detected if presented in the wrong modality;
- some biometric systems present accessibility problems (e.g. fingerprint recognition may not be accessible for people with low hand dexterity).

Solutions include:

- feedback that identifies that sensing is taking place and success/failure feedback should be multimodal i.e. the feedback should be simultaneously presented in at least two modalities;
- provision of multiple sensing/identification technologies that work in combination (to strengthen reliability) and separately (to provide accessible alternatives and for use in case of a single system failure);
- biometric systems to be used should adapt to user's needs and preferences.

People considering the use of recognition/mood/activity-based input technologies in ICT devices and services can find additional useful insights and information in the following sources: [Stephanidis, 2009], [Stephanidis, 2007] (general accessibility issues related to recognition/mood/activity-based input technologies); [Haans, Ijsselsteijn, & Kort, 2008], [Tilton, 2002], [Xueyan, & Shuxu, 2008] (direct interaction person recognition); [Orr, & Abowd, 2000] (remote interaction person recognition); [Belt, Greenblatt, Häkkilä, & Mäkelä, 2006], [Bravo, Hervas, Chavira, Nava, & Villarreal, 2008], [Want, Fishkin, Gujar, & Harrison, 1999] (object-recognition based); [Boverie, 2004], [Brugnoli, Rowland, Morabito, Davide, & Doughty, 2006]; [Ruffini et al., 2007] (mood/activity sensing); [Konomi, 2004], [Langheinrich, 2005], [ISO/IEC TR 24714-1], [Yousefi, Jalili, & Niamanesh, 2006] (privacy related to recognition-based input technologies).

Table 6.5.1 gives an alphabetical listing of the technologies covered in this clause.

**Table 6.5.1: Overview of recognition/mood/activity-based input technologies**

| User interaction technology | Sub category | Table |
|---|---|---|
| Dry electrode physiological monitoring | Mood/activity sensing | 6.5.14 |
| Eye-lid monitoring | Mood/activity sensing | 6.5.12 |
| Facial recognition | Remote interaction person recognition | 6.5.7 |
| Hand shape recognition | Direct interaction person recognition | 6.5.3 |
| Hand vein recognition | Direct interaction person recognition | 6.5.5 |
| Iris recognition | Direct interaction person recognition | 6.5.2 |
| Keystroke dynamics recognition | Direct interaction person recognition | 6.5.4 |
| Multi-camera eye sensing | Mood/activity sensing | 6.5.13 |
| NFC tag sensing | Object-recognition based user interaction | 6.5.11 |
| Retinal blood vessel recognition | Direct interaction person recognition | 6.5.6 |
| RFID tag sensing | Object-recognition based user interaction | 6.5.10 |
| Smart floor gait analysis | Remote interaction person recognition | 6.5.9 |
| Speaker recognition | Remote interaction person recognition | 6.5.8 |

**Table 6.5.2: Iris recognition**

| Characteristic | Definition |
|---|---|
| Name | Iris recognition |
| Description | Iris recognition uses camera technology to record a mathematical representation of the iris. This sample is compared against a previously stored template to determine if there is a sufficiently accurate match. |
| Mass market deployment | By 2012 |
| Sub category | Direct interaction person recognition |
| Related technology | Cameras |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Blind users will be unable to see any cameras associated with the iris recognition system.<br>- Any warnings that iris recognition-based identification will be undertaken may be missed by people with disabilities according to their disability (e.g. blind users may miss written signs or symbols and deaf users will not hear spoken warnings).<br>- Where the user is required to get close to the camera, people with mobility impairments and people who are short may have problems using the system. |
| Solutions related to accessibility barriers | - Multimodal feedback: people should be alerted that iris recognition-based identification is taking place. This should be done so that the user is warned in such a way that they can avoid being recognized before entering the recognition zone or before the recognition process commences. Warnings should be given in a multi-modal way (e.g. text/symbols and spoken warnings).<br>- User limitation compensation: a means to assist blind users to correctly align their eyes with the camera should be provided (e.g. physical guidance cues to aid head alignment or a human helper).<br>- User limitation compensation: adapt camera position/characteristics to the needs of people with mobility impairments.<br>- User limitation compensation: the provision of a human helper to assist all people with disabilities.<br>- User limitation compensation: provide an alternative means to achieve recognition. |

| Characteristic | Definition |
| --- | --- |
| Cultural issues | - In some cultures or settings it may be considered inappropriate to use sensing technologies to recognize people.<br>- Although it may be difficult and uncommon, iris recognition can be done in such a way that the subject is unaware that they are being recognized. Issues related to the privacy implications of the non-consensual use of iris recognition may vary significantly between cultures - with some cultures being very strongly against the use of such mechanisms under any circumstances (except possibly for use against criminals and terrorists). |
| Benefit for all users | - Few people can not use the technology, as most individuals have at least one eye. In a few instances even blind persons have used iris recognition successfully, as the technology is iris pattern-dependent, not sight dependent.<br>- As the iris pattern is very stable, re-enrolment should not be required unless a rare event known to affect the iris has occurred. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - The smallest outlier population of all biometrics.<br>- Iris pattern and structure exhibit long-term stability.<br>- Only certain traumas, rare diseases or some ophthalmologic surgical procedures can change the iris pattern.<br>- Ideally suited for identification as well as verification/authentication as it is designed to work in rapid exhaustive search mode independent of database size.<br>- Can be performed without the need for laser or bright lights (although near-IR illumination enhances the identification of darker pigmented irises).<br>- Cameras can be automatically adjusted to identify and track the iris of a subject in order to take the readings without the subject having to precisely align themselves with some measurement equipment. |
| Deployment cons | - Best results are obtained if the recognition takes place using near-infrared illumination (especially for people with darkly pigmented irises) - which both limit the range and positioning within which recognition can take place and may also increase user fears about intrusiveness and possible danger.<br>- Where automatic remote iris recognition takes place, the user may be unaware that recognition is taking place.<br>- Iris recognition systems can be used to identify a person without their knowledge or consent. If this is done without alerting the subject that recognition is taking place there is a risk that many people will perceive this as an invasion of privacy and a breaking of trust.<br>- The cameras associated with the iris recognition system may not be very visible. |
| Implementation requirements | - Wherever possible recognition using visible light should be used in order to reassure users and provide the maximum flexibility in the positioning of the subject relative to the cameras (hopefully performance of visible light systems will continue to improve over time). |
| Harmonization | - At the time of writing, ISO/IEC JTC 1/SC37/WG6 have created a proposal Proposal for "Icons and Symbols for Use in biometric Systems" proposes symbols for Iris Recognition and "Presenter's Body Position and Direction" (Move Forward, Move Backward, Move Left, Move Right) |

**Table 6.5.3: Hand shape recognition**

| Characteristic | Definition |
|---|---|
| Name | Hand shape recognition |
| Description | Uses the geometrical aspects of parts of the hand such as finger length, thickness and curvature for the purposes of recognizing a person by matching the observed characteristics with the stored hand characteristics template. |
| Mass market deployment | By 2012 |
| Sub category | Direct interaction person recognition |
| Related technology | Cameras |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Unsuitable for people with no hands or for people who can not move their hands or who can not place them on a surface where they are analyzed.<br>- People with visual impairments may have problems locating the place where the hand should be placed. |
| Solutions related to accessibility barriers | - User limitation compensation: providing a human assistant to aid people with visual impairments or those with limited or no motor control over their upper body extremities.<br>- User limitation compensation: provide an alternative means to achieve recognition. |
| Cultural issues | - In some cultures or settings it may be considered inappropriate to use sensing technologies to recognize people. |
| Benefit for all users | - Very easy to use.<br>- A technique that makes it clear that a recognition process is taking place without any significant user discomfort or perceived danger. |
| Benefits for older people and people with disabilities | - It should be clear that this technique is suitable or unsuitable (e.g. no hands) and hence there is a low risk of unintended embarrassment due to inappropriate use of the technique. |
| Deployment pros | - A technique that is easy for people to use.<br>- If sufficient measurements are made, hand geometry can be a highly individual thing and hence lead to good recognition rates.<br>- Recognition is fast (as is enrolment). |
| Deployment cons | - Cuts, bruises, swellings and other medical conditions can have a temporary affect on the hand shape pattern, causing recognition failure.<br>- Loss of fingers will cause recognition failure and may require re-enrolment.<br>- Easier to defraud the system than some other techniques if the system relies solely on hand geometry (as a model of a hand could theoretically be used). |
| Implementation requirements | - There is a requirement to provide a defined location where the hand needs to be placed in order to be sensed |
| Harmonization | None identified |

**Table 6.5.4: Keystroke dynamics recognition**

| Characteristic | Definition |
|---|---|
| Name | Keystroke dynamics recognition |
| Description | Measuring of the manner and rhythm in which an individual types characters on a keyboard or keypad in order to compare the observed pattern to the previously measured characteristics of an individual in order to recognize that person. |
| Mass market deployment | By 2015 |
| Sub category | Direct interaction person recognition |
| Related technology | Keyboards |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - No general accessibility issues identified (assuming that this technique will not be used where a person is unable to type due to a disability).<br>- It is unknown whether keystroke dynamics recognition techniques will be usable to people who use a stick as an assistive device whilst typing. |
| Solutions related to accessibility barriers | - In some cultures or settings it may be considered inappropriate to use sensing technologies to recognize people. |
| Cultural issues | - As it is an inherently hidden technique, there may be deep suspicion in many national and corporate cultures that keystroke recognition may be abused to perform "hidden", possibly unlawful, recognition and surveillance e.g.in the workplace or in (semi-) public places or systems. |
| Benefit for all users | - Does not require special hardware for those normally using keyboards.<br>- Completely non-invasive. |
| Benefits for older people and people with disabilities | - If normal keyboard usage is possible, then this method of verification will be suitable. |
| Deployment pros | - The technology is not (currently) really suitable for use in identification systems (only for verification/authentication).<br>- Keystroke dynamics can vary significantly according to factors such as the degree of alertness or emotional state of the subject - leading to the risk of false negatives and positives. |
| Deployment cons | - Not suitable for people who are unable to use a keyboard for general user interaction (e.g. people with no hands, people with a severe tremor). |
| Implementation requirements | - A keyboard or similar input device is required. |
| Harmonization | None identified |

**Table 6.5.5: Hand vein recognition**

| Characteristic | Definition |
|---|---|
| Name | Hand vein recognition |
| Description | The recognition of personally unique palm or finger vein patterns from a hand illuminated by near infrared light and its comparison to personal templates stored in a database. |
| Mass market deployment | By 2015 |
| Sub category | Direct interaction person recognition |
| Related technology | Cameras |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Unsuitable for people with no hands or with medical conditions that make the use of this technology (temporarily) impossible.<br>- Unsuitable for people who cannot move their hands.<br>- Unsuitable for people who cannot see the surface on which their hands should be placed. |
| Solutions related to accessibility barriers | - User limitation compensation: providing a human assistant to aid people with visual impairments or those with limited or no motor control over their upper body extremities.<br>- User limitation compensation: provide an alternative means to achieve recognition. |
| Cultural issues | - In some cultures or settings it may be considered inappropriate to use sensing technologies to recognize people. |
| Benefit for all users | - Very easy to use.<br>- A technique that makes it clear that a recognition process is taking place without any significant user discomfort or perceived danger. |
| Benefits for older people and people with disabilities | - It should be clear that this technique is suitable or unsuitable (e.g. no hands) and hence there is a low risk of unintended embarrassment due to inappropriate use of the technique. |
| Deployment pros | - A technique that is easy for people to use.<br>- Vein patterns are highly unique and hence the success rate for recognition is high.<br>- Difficult to defraud the system (veins are difficult to simulate as they lie under the skin).<br>- Recognition is fast (as is enrolment). |
| Deployment cons | None identified |
| Implementation requirements | - There is a requirement to provide a defined location where the hand needs to be placed in order to be sensed. |
| Harmonization | None identified |

**Table 6.5.6: Retinal blood vessel recognition**

| Characteristic | Definition |
|---|---|
| Name | Retinal blood vessel recognition |
| Description | A scan of a person's eye, using low-energy infrared light, records the unique pattern of blood vessels on the back of the retina. This scan is then compared against a previously stored template to determine if there is a sufficiently accurate match. |
| Mass market deployment | After 2015 |
| Sub category | Direct interaction person recognition |
| Related technology | Cameras |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>11 Not cause personal risk (e.g. seizure)<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Blind people may have great difficulty aligning their eyes with the camera.<br>- People with pronounced nystagmus (tremor of the eyes) may also experience problems.<br>- Measurement accuracy can be affected by a disease such as cataracts and severe astigmatism.<br>- Where the user is required to get close to the camera, people with mobility impairments and people who are short may have problems using the system. |
| Solutions related to accessibility barriers | - This technique should only be deployed where secure verification is generally accepted to be a high priority for use of the eService.<br>- User limitation compensation: a means to assist blind users to correctly align their eyes with the camera should be provided (e.g. physical guidance cues to aid head alignment or a human helper).<br>- User limitation compensation: adapt camera position/characteristics to the needs of people with mobility impairments.<br>- User limitation compensation: the provision of a human helper to assist all people with disabilities.<br>- User limitation compensation: provide an alternative means to achieve recognition. |
| Cultural issues | - In some cultures or settings it may be considered inappropriate to use sensing technologies to recognize people. |
| Benefit for all users | None identified |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - Each person's retina is unique; hence it is a technique that produces few false positives and almost zero false negatives.<br>- Recognition is fast (as is enrolment). |
| Deployment cons | - Not a very practical technique for general user identification due to the need for an individual to be close to and correctly aligned with a camera to be identified.<br>- Really a verification/authentication technique.<br>- Even though illuminating the eye with low-energy infrared light may be safe, users may perceive a risk of danger.<br>- Users may find the process of having to present their eye in a very precise location close to the camera optics in order for it to be illuminated as something that causes them psychological and possibly physical discomfort.<br>- Fears and discomfort are factors that may create user resistance to the use of this technology in applications where the need for precise verification or identification can be seen to be critical to the use of the eService.<br>- Currently equipment costs are high. |
| Implementation requirements | - There is a requirement to provide a defined location where the eye should be positioned in order to be sensed. |
| Harmonization | None identified |

**Table 6.5.7: Facial recognition**

| Characteristic | Definition |
|---|---|
| Name | Facial recognition |
| Description | A facial recognition system uses a digital still or a video image to recognize a person by comparing selected facial features with stored face data templates to identify a match. A more sophisticated, but less flexible, variant uses taking 3-D images of the face (which makes the recognition less subject to factors such as unusual lighting conditions and the wearing of prominent makeup). |
| Mass market deployment | By 2012 |
| Sub category | Remote interaction person recognition |
| Related technology | Cameras, 3-D imaging sensors |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Blind users will be unable to see any cameras associated with the facial recognition system, which represents a greater risk that the person will be recognized when they do not wish to be (a differential increase in privacy invasion for blind users).<br>- Any warnings that facial recognition-based identification will be undertaken may be missed by people with disabilities according to their disability (e.g. blind users may miss written signs or symbols and deaf users will not hear spoken warnings). |
| Solutions related to accessibility barriers | - Multimodal presentation: people should be alerted that facial recognition-based identification is taking place. This should be done so that the user is warned in such a way that they can avoid being recognized before entering the recognition zone or before the recognition process commences. Warnings should be given in a multi-modal way (e.g. text/symbols and spoken warnings).<br>- User limitation compensation: provide an alternative means to achieve recognition. |
| Cultural issues | - In some cultures or settings it may be considered inappropriate to use sensing technologies to recognize people.<br>- Facial recognition can be done in such a way that the subject is unaware that they are being recognized. Issues related to the privacy implications of the non-consensual use of facial recognition may vary significantly between cultures - with some cultures being very strongly against the use of such mechanisms under any circumstances (except possibly for use against criminals and terrorists). |
| Benefit for all users | - This is a universal biometric - everyone has a face, therefore everyone can enrol.<br>- This is a non-intrusive method requiring no physical contact and no worrying forms of specialized illumination.<br>- A fast technology. The face can be found almost instantly in a video stream and analysis takes place very rapidly (in say 1.5 seconds). |
| Benefits for older people and people with disabilities | - If one or more cameras are carefully placed, it will not be necessary for the subject of the recognition to know precisely where to stand (or sit) and where to look. This makes the technique very convenient for people who are blind, seated in a wheelchair, etc. |
| Deployment pros | - Recognition of a single face in a scene with many faces is comparatively easy and much easier than with other techniques. |
| Deployment cons | - Even using the most sophisticated techniques it is not the most reliable means of identification as it is subject to many confounding factors such as lighting, facial expression, glasses, makeup, recent facial scars, facial hair, etc.<br>- Facial recognition systems can be used to identify a person without their knowledge or consent. If this is done without alerting the subject that recognition is taking place there is a risk that many people will perceive this as an invasion of privacy and a breaking of trust.<br>- The cameras may not be very visible, which may be perceived as strengthening the risk of unwelcome privacy invasion. |
| Implementation requirements | - Facial recognition should only be deployed on its own in situations where mistaken recognition does not have serious or irreversible consequences.<br>- Facial recognition is an easy to administer recognition technique that can be used in conjunction with other compatible techniques such as iris recognition to provide good multi-factor authentication/identification. |

| Characteristic | Definition |
|---|---|
| Harmonization | - At the time of writing, ISO/IEC JTC 1/SC37/WG6 have created a proposal for "Icons and Symbols for Use in biometric Systems" proposes symbols for Face Recognition and "Presenter's Body Position and Direction" (Move Forward, Move Backward, Move Left, Move Right). |

**Table 6.5.8: Speaker recognition**

| Characteristic | Definition |
|---|---|
| Name | Speaker recognition |
| Description | The computing task of recognizing a person using characteristics extracted from their voices. There is a difference between speaker recognition (recognizing who is speaking) and speech recognition (recognizing what is being said). Speaker recognition can be done using a pre-defined passage of text (text-dependent) or from analysing general speech (text-independent). For text dependent recognition, the subject needs to speak the same text that was used in the enrolment phase of the recognition process.<br><br>Text-dependent systems are most frequently used in verification/authentication systems. In one variant of such systems, knowledge of what the correct text passage is provides another factor in the authentication process (turning this from a single-factor to a multi-factor authentication process). This only works well where the text passage used for enrolment and testing is unique to each individual.<br><br>Text-independent systems are ideally suited to speaker identification systems as they can be performed without the explicit active co-operation of the speaker during the identification process. Even the enrolment process can be done without the active co-operation of the subject (and possibly without their knowledge). |
| Mass market deployment | After 2012 |
| Sub category | Remote interaction person recognition |
| Related technology | Microphones, Noise reduction technologies |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - This technique will not work reliably for users who are unable to speak consistently and clearly.<br>- Blind users will be unable to see any microphones associated with the speaker recognition system (and they may not be very visible to other users).<br>- Any warnings that text-independent speaker identification will be undertaken may be missed by people with disabilities according to their disability (e.g. blind users may miss written signs or symbols and deaf users will not hear spoken warnings). |
| Solutions related to accessibility barriers | - Multimodal presentation: people should be alerted that text-independent identification is taking place. This should be done so that the user is warned in such a way that they can avoid being recognized before entering the recognition zone or before the recognition process commences. Warnings should be given in a multi-modal way (e.g. text/symbols and spoken warnings).<br>- User limitation compensation: provide an alternative means to achieve recognition. |
| Cultural issues | - In some cultures or settings it may be considered inappropriate to use sensing technologies to recognize people.<br>- Issues related to the privacy implications of the non-consensual use of text-independent speaker identification may vary significantly between cultures - with some cultures being very strongly against the use of such mechanisms under any circumstances (except possibly for use against criminals and terrorists). |
| Benefit for all users | - Speaker recognition is potentially one of the least intrusive recognition technologies in terms of the requirements placed on the subject being recognized (this same characteristic leads to a perceived disadvantage in relation to privacy infringement issues). |

| Characteristic | Definition |
|---|---|
| Benefits for older people and people with disabilities | - This technology is very easy to use for all people apart from those who are unable to speak clearly and consistently. |
| Deployment pros | - This technology places minimal requirements on the user in terms of their positioning in relation to the microphone and what they say (in the case of text-independent recognition).<br>- This technology cannot be perceived as physically threatening in any way (e.g. no physical contact (hence no germ transmission concerns), no lights shone into eyes (hence no fear of physical damage to body parts). |
| Deployment cons | - Ambient noise levels will always have a negative impact on speaker recognition performance (although noise reduction technologies can be used to minimise such effects).<br>- Text-independent identification systems can be used to identify a person without their knowledge or consent. If this is done without alerting the subject that recognition is taking place there is a risk that many people will perceive this as an invasion of privacy and a breaking of trust. |
| Implementation requirements | None identified |
| Harmonization | - At the time of writing, ISO/IEC JTC 1/SC37/WG6 have created a proposal for "Icons and Symbols for Use in biometric Systems" proposes symbols for Voice Recognition and "Presenter's Body Position and Direction" (Move Forward, Move Backward, Move Left, Move Right). |

**Table 6.5.9: Smart floor gait analysis**

| Characteristic | Definition |
|---|---|
| Name | Smart floor gait analysis |
| Description | A system for identifying people based on their footstep force profile features measured by a "smart floor" (load cells located under floor tiles connected to a data acquisition system). The measured results are compared against stored models based on footstep profile features in order to identify the person walking on the floor. |
| Mass market deployment | After 2015 |
| Sub category | Remote interaction person recognition |
| Related technology | None identified |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - These techniques will not work when used with people who are using a walking aid or a wheelchair. |
| Solutions related to accessibility barriers | - User limitation compensation: provide an alternative means to achieve recognition. |
| Cultural issues | - In some cultures or settings it may be considered inappropriate to use sensing technologies to recognize people. |
| Benefit for all users | No special actions are required in order to be identified. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - There is no need to provide a special place to locate the recognition system (no room space wasted).<br>- There is no visual intrusion into the environment. |
| Deployment cons | - These technologies can be very costly to install and require the complete floor (or a section on which everyone can be guaranteed to walk) to be replaced.<br>- Maintenance of smart floors can be costly and disruptive due to the need to lift floor sections to do maintenance.<br>- The accuracy of the different variants of smart floor gait analysis is not yet proven. |
| Implementation requirements | - There is either a need for the current floor to be removed to install new smart floor flooring, or a need for sufficient ceiling height to be able to install new smart floor flooring above the original flooring. |
| Harmonization | None identified |

**Table 6.5.10: RFID tag sensing**

| Characteristic | Definition |
|---|---|
| Name | RFID tag sensing |
| Description | Objects that have radio frequency identification (RFID) technology tags attached can be uniquely identified by RFID sensing technology in user equipment and can be integrated as part of a user interaction dialogue. |
| Mass market deployment | By 2012 |
| Sub category | Object-recognition based user interaction |
| Related technology | NFC tag sensing |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Visually impaired users may not be able to see where to place the object. |
| Solutions related to accessibility barriers | - Multimodal feedback: give multimodal feedback on completion and attempts. |
| Cultural issues | - Where recognition of the object is indirectly used to recognize a person, this may be considered inappropriate in some cultures or settings. |
| Benefit for all users | - Interaction with a service can be initiated by simply bringing the user equipment into close proximity to the RFID tagged object. |
| Benefits for older people and people with disabilities | - Just placing an object near the user equipment (e.g. mobile phone) or moving the user equipment to the RFID tagged object is a very simple concept for people with cognitive or learning disabilities to understand.<br>- The benefit for people with cognitive or learning disabilities can be enhanced if the RFID tagged object is has strong associations with the intended operation (e.g. a tagged object that has an image of a person on it can be used to initiate a telephone call to that person).<br>- Placing an RFID tagged object in a wheelchair may support people with mobility impairments to trigger certain events when they approach a certain location. |
| Deployment pros | - This only requires the fitting of an RFID reading device in the user equipment and the tagging of significant objects. |
| Deployment cons | - There is a cost per user equipment and per object to be tagged. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.5.11: NFC tag sensing**

| Characteristic | Definition |
|---|---|
| Name | NFC tag sensing |
| Description | Objects that have Near Field Communication (NFC) technology tags attached can be uniquely identified by NFC sensing technology in user equipment and can be integrated as part of a user interaction dialogue. |
| Mass market deployment | By 2012 |
| Sub category | Object-recognition based user interaction |
| Related technology | RFID tag sensing |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | – - Visually impaired users may not be able to see where to place the object. |
| Solutions related to accessibility barriers | - Multimodal feedback: give multimodal feedback on completion and attempts. |
| Cultural issues | - Where recognition of the object is indirectly used to recognize a person, this may be considered inappropriate in some cultures or settings. |
| Benefit for all users | - Interaction with a service can be initiated by simply bringing the user equipment into close proximity to the NFC tagged object. |
| Benefits for older people and people with disabilities | - Just placing an object near the user equipment (e.g. mobile phone) or moving the user equipment to the NFC tagged object is a very simple concept for people with cognitive or learning disabilities to understand.<br>- The benefit for people with cognitive or learning disabilities can be enhanced if the NFC tagged object is has strong associations with the intended operation (e.g. a tagged object that has an image of a person on it can be used to initiate a telephone call to that person). |
| Deployment pros | - This only requires the fitting of an NFC reading device in the user equipment and the tagging of significant objects. |
| Deployment cons | - There is a cost per user equipment and per object to be tagged. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.5.12: Eye-lid monitoring**

| Characteristic | Definition |
|---|---|
| Name | Basic eye-lid monitoring (camera) |
| Description | Camera-based observation of the frequency and duration of eye-lid closure in order to assess the state of alertness of the person being observed. |
| Mass market deployment | By 2012 |
| Sub category | Mood/activity sensing |
| Related technology | Cameras<br>Multi-camera eye sensing |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Users with involuntary eye-lid movements may be misunderstood by the system. |
| Solutions related to accessibility barriers | - User limitation compensation: design system to ignore involuntary eye-lid movements. |
| Cultural issues | - In some cultures or settings it may be considered inappropriate to use sensing technologies to infer things about a person's physiological state or what they are doing. |
| Benefit for all users | - This technology can be of benefit to all users in situations where drowsiness may be hazardous (e.g. driving a motor vehicle). |
| Benefits for older people and people with disabilities | - Alertness can be automatically assessed, which means that those unable to explicitly communicate their internal state can provide that information to an eService. This is likely to be of relevance in certain eHealth and Telecare applications. |
| Deployment pros | - Technology of this type is likely to be present in cars in order to assess alertness suitable for safe driving.<br>- Availability in cars offers the possibility to use the technology for other forms of service interaction than driving safety assessment. |
| Deployment cons | - Requires a comparatively fixed position and direction of the subject's head in order to work (not a problem in cars but a serious limitation in many other situations). |
| Implementation requirements | - See deployment cons. |
| Harmonization | None identified |

**Table 6.5.13: Multi-camera eye sensing**

| Characteristic | Definition |
|---|---|
| Name | Multi-camera eye sensing |
| Description | A multi-camera platform for monitoring eyelid and eye gaze. Used for detecting focus of attention and alertness (particularly relevant in high vigilance applications). |
| Mass market deployment | By 2015 |
| Sub category | Mood/activity sensing |
| Related technology | Cameras<br>Eye-lid monitoring |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | None identified |
| Solutions related to accessibility barriers | None identified |
| Cultural issues | - In some cultures or settings it may be considered inappropriate to use sensing technologies to infer things about a person's physiological state or what they are doing. |
| Benefit for all users | - This technology can be of benefit to all users in situations where drowsiness may be hazardous (e.g. driving a motor vehicle). |
| Benefits for older people and people with disabilities | - Alertness can be automatically assessed, which means that those unable to explicitly communicate their internal state can provide that information to an eService. This is likely to be of relevance in certain eHealth and Telecare applications. |
| Deployment pros | - If this technology is deployed for the purpose of drowsiness detection in cars, there is the possibility to use the technology for other forms of service interaction than driving safety assessment.<br>- This should have better performance than basic eye-lid monitoring with a simple camera. |
| Deployment cons | - Requires a comparatively fixed position and direction of the subject's head in order to work (not a problem in cars but a serious limitation in many other situations). |
| Implementation requirements | - See deployment cons. |
| Harmonization | None identified |

**Table 6.5.14: Dry electrode physiological monitoring**

| Characteristic | Definition |
|---|---|
| Name | Dry electrode physiological monitoring |
| Description | The monitoring of a range of physiological measures related to mood and/or activity, such as electroencephalography (EEG), by means of dry electrode sensors in contact with the forehead (e.g. sensors using Carbon Nanotube technology). |
| Mass market deployment | After 2015 |
| Sub category | Mood/activity sensing |
| Related technology | None identified |
| User requirements | 03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Solutions related to accessibility barriers | None identified. |
| Accessibility barriers | None identified |
| Cultural issues | - In some cultures or settings it may be considered inappropriate to use sensing technologies to infer things about a person's physiological state or what they are doing.<br>- In many contexts, the wearing of any head-mounted device might be socially unacceptable. |
| Benefit for all users | - This technology could potentially be used in various telecare situations. It might also be very useful in various entertainment situations (e.g. games). |
| Benefits for older people and people with disabilities | - It is likely that the telecare uses may be more required by older people and people with disabilities. |
| Deployment pros | - There is no need to use a conductive gel under the electrodes as is required for all other technologies. This will make this technology more acceptable to the mass market. |
| Deployment cons | - The wearing of a head-mounted device may be too inconvenient or socially unacceptable to permit its widespread usage.<br>- Some concerns have been expressed over the medical safety of the carbon nanotube technology. |
| Implementation requirements | - The means of attaching the sensors to the body needs to be done in a way that is both convenient for users and yet effective in terms of getting accurate physiological measures. |
| Harmonization | None identified |

## 6.6 Smell-based input technologies roadmap

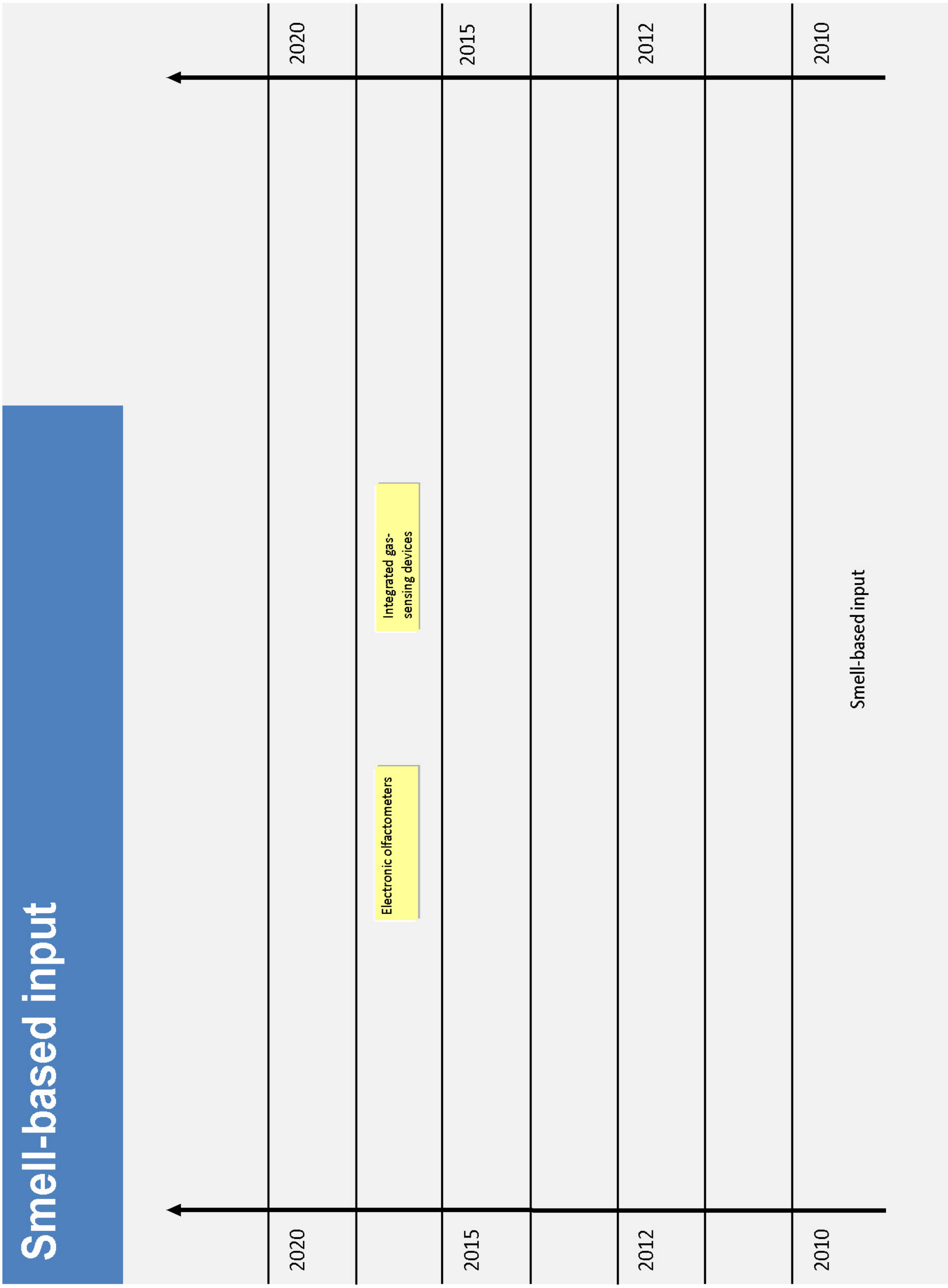


**Figure 6.6.1: Smell-based input technologies roadmap**

The use of smell as an input means has so far not been an option for the design of interactive systems. There are a number of inherent issues which need to be dealt with when trying to use smell in a user interface:

- It is unclear how to create smell "on request".
- There is a rather long hysteresis between the time when smell is created and the time the recognition means detect the presence of smell.
- There is currently no clear understanding how to interpret smell.

In the past smell has mostly been used to detect hazardous environmental situations and specific medical emergency situation (e.g. breath analysis). Nevertheless, it might be possible to detect and correctly interpret certain human-induced smell which gives indications of the state of a user (e.g. to detect the stress level of user).

The issues listed above lead to the fact that smell should not be used as a unique input modality but should always only be used as one modality in a multimodal input environment. It is not expected that such a technology will mature in the near future.

Table 6.6.1 gives an alphabetical listing of the technologies covered in this clause.

**Table 6.6.1: Overview of smell-based input technologies**

| User interaction technology | Sub category | Table |
|---|---|---|
| Electronic olfactometers | Smell-based input | 6.6.2 |
| Integrated gas-sensing devices | Smell-based input | 6.6.3 |

**Table 6.6.2: Electronic olfactometers**

| Characteristic | Definition |
|---|---|
| Name | Electronic olfactometers |
| Description | Electronic olfactometers have been in use for the recognition of hazardous environmental events (e.g. smoke detectors). They can be used to recognize various different smells based on the molecules in the analyzed air. |
| Mass market deployment | After 2015 |
| Sub category | Smell-based input |
| Related technology | Integrated gas-sensing devices<br>Mood/activity sensing |
| User requirements | 06 Be able to invoke and carry out all actions<br>08 Avoiding unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product |
| Accessibility barriers | - It is impossible to create smell on demand (except with technical means). |
| Solutions related to accessibility barriers | - Low complexity and multimodal control: provide easy to use input technology and alternate modality for input. |
| Cultural issues | Interpretation of smell may vary in different cultures. |
| Benefit for all users | - Potential security feature.<br>- Enables new sensual data transmission.<br>- Enables rich communication. |
| Benefits for older people and people with disabilities | - Potential alternate communication path to transmit information (e.g. breathing into a sensor to activate controls). |
| Deployment pros | None identified |
| Deployment cons | - Difficult to control.<br>- Potentially long delay between user activation and recognition.<br>- High energy use.<br>- Difficult to use in user interaction due to interpretation issues. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.6.3: Integrated gas-sensing devices**

| Characteristic | Definition |
|---|---|
| Name | Integrated gas-sensing devices |
| Description | Integrated gas-sensing devices work very similar to electronic olfactometers. Recognition technologies include physical and chemical technologies which are beyond the scope of the present document. |
| Mass market deployment | After 2015 |
| Sub category | Smell-based input |
| Related technology | Electronic olfactometers<br>Mood/activity sensing |
| User requirements | 06 Be able to invoke and carry out all actions<br>08 Avoiding unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product |
| Accessibility barriers | - It is impossible to create smell on demand (except with technical means). |
| Solutions related to accessibility barriers | - Low complexity and multimodal control: provide easy to use input technology and alternate modality for input. |
| Cultural issues | - Interpretation of smell may vary in different cultures. |
| Benefit for all users | - Potential security feature.<br>- Enables new sensual data transmission.<br>Enables rich communication. |
| Benefits for older people and people with disabilities | - Potential alternate communication path to transmit information (e.g. breathing into a sensor to activate controls). |
| Deployment pros | None identified |
| Deployment cons | - Difficult to control.<br>- Potentially long delay between user activation and recognition.<br>- High energy use.<br>- Difficult to use in user interaction due to interpretation issues. |
| Implementation requirements | None identified |
| Harmonization | None identified |

## 6.7 Touch-based input technologies roadmaps

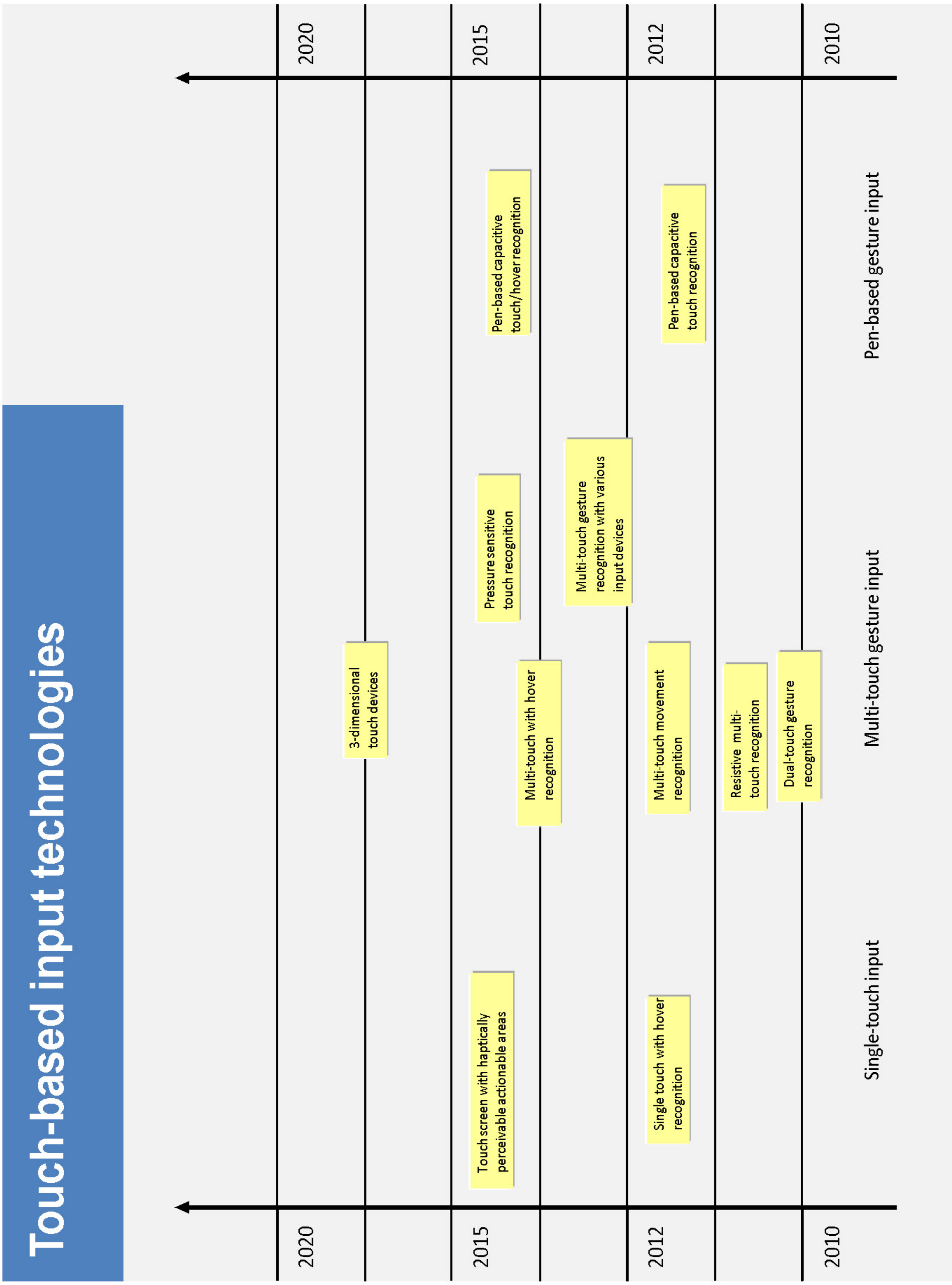


**Figure 6.7.1: Touch-based input technologies roadmap**

Touch screens and touch recognition together with still limited recognition of gestures using one or more fingers on a touch screen are, or are rapidly becoming, state of the art. While they offer a wealth of innovative design and implementation options they also cause inclusive design issues, namely for people with low visual abilities and users with poor motion control.

Touch input devices offer interesting solutions for many of the accessibility issues created by the initial deployment of devices with this technology, e.g. gesture-based interfaces can be enhanced by simple point-and-click touch command interfaces to overcome the problem of remembering complex gesture languages. Their introduction into the mass market is potentially quite positive for many people with various impairments as they allow for interesting multi-modal interface designs.

Issues still to be addressed in the development of touch-based input technologies are:

- Gesture interfaces are potentially based on complex gesture languages which:
  - should be subject to harmonization activities; and
  - may be extremely hard to recognize and remember for people with cognitive impairments and learning-related barriers.
- Actionable areas on a touch screen may be extremely hard to identify by users with impaired vision.
- All gesture recognition based interactions may potentially be unusable for people with upper limb impairments (e.g. hand tremor, poor movement coordination, poor hand dexterity, people using an assistive device for touching).
- Most touch input technologies require hand-eye coordination (e.g. by doing a gesture, one option in a visual menu is selected), which excludes many users with visual impairments.
- All touch-based input technologies have to deal with timing issues, i.e. the ergonomically optimal time between button touch or release action by the user and the system reaction following these user actions. The definition of these time delays is a potential subject of harmonization and/or standardization activities.

The following table gives an alphabetical listing of the technologies covered in this clause.

**Table 6.7.1: Overview of touch-based input technologies**

| User interaction technology | Sub category | Table |
|---|---|---|
| 3-dimensional touch devices | Multi-touch gesture input | 6.7.10 |
| Dual-touch gesture recognition | Multi-touch gesture input | 6.7.4 |
| Multi touch with hover recognition | Multi-touch gesture input | 6.7.8 |
| Multi-touch movement recognition | Multi-touch gesture input | 6.7.7 |
| Multi-touch gesture recognition with various input devices | Multi-touch gesture input | 6.7.6 |
| Pen-based capacitive touch recognition | Pen-based gesture input | 6.7.11 |
| Pen-based capacitive touch/hover recognition | Pen-based gesture input | 6.7.12 |
| Pressure sensitive touch recognition | Multi-touch gesture input | 6.7.9 |
| Resistive multi-touch recognition | Multi-touch gesture input | 6.7.5 |
| Single touch with hover recognition | Single touch input | 6.7.2 |
| Touch screen with haptically perceivable actionable areas | Single touch input | 6.7.3 |

**Table 6.7.2: Single touch with hover recognition**

| Characteristic | Definition |
|---|---|
| Name | Single touch with hover recognition |
| Description | Single touch with hover recognition is the ability of a touch-sensitive display to recognize one finger at a distance of the recognizing surface. This allows for:<br>(i) prediction of touch in a specific area,<br>(ii) recognition of exact 3-dimensional coordinates relative to the touch screen with the z-axis being the distance of the digitizer to the surface of the display area, and<br>(iii) the recognition of 3-dimensional single-point movement. |
| Mass market deployment | By 2015 |
| Sub category | Single touch input |
| Related technology | Pen-based capacitive touch/hover recognition<br>Multi touch with hover recognition |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Visually impaired users may have a problem identifying actionable components on the touch screen.<br>- Visually impaired users may not be able to recognize the system reaction after execution of an actionable component.<br>- People with upper limb impairments may have problems to use this technology. |
| Solutions related to accessibility barriers | - Equivalent simultaneous control: implement simple button command interface as alternative.<br>- Multimodal control: implement multimodal input and output mechanisms. |
| Cultural issues | - Possibly hygienic restrictions with public interfaces. |
| Benefit for all users | - Allows feedback to all users based on proximity to an actionable display area. |
| Benefits for older people and people with disabilities | - Good to use for low-dexterity users.<br>- Allows for efficient feedback for visually impaired users. |
| Deployment pros | Enables easy-to-use touch-screen based button interfaces. |
| Deployment cons | - Potential wrong interpretation and activation of controls based on proximity.<br>- Visually impaired users will not recognize actionable surface areas. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.7.3: Touch screen with haptically perceivable actionable areas**

| Characteristic | Definition |
|---|---|
| Name | Touch screen with haptically perceivable actionable areas |
| Description | Touch screens with haptically perceivable actionable areas allow for displays in which areas of a touch screen can be elevated to allow for identification of active touch screen areas. The elevation of sections of the touch screen is done by micro-mechanical mechanical devices. |
| Mass market deployment | By 2015 |
| Sub category | Single touch input |
| Related technology | Piezo-electric actuation<br>Dielectric elastomers<br>Pneumatic systems |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Users with low haptic abilities may have a problem recognizing actionable components. |
| Solutions related to accessibility barriers | - Design UI for touch screen use without haptic output.<br>- Multimodal user interface design. |
| Cultural issues | - Possibly hygienic restrictions with public interfaces. |
| Benefit for all users | - Allows identification of controls without requiring visual attention.<br>- Provides more accurate action control. |
| Benefits for older people and people with disabilities | - Allows accurate positioning of fingers on a touch screen for users with limited movement control (jitter). |
| Deployment pros | - Allows perfect identification of actionable components in "eyes-free" environment. |
| Deployment cons | - Potentially high energy consumption. |
| Implementation requirements | - Due to high energy consumption powerful batteries required. |
| Harmonization | None identified |

**Table 6.7.4: Dual-touch gesture recognition**

| Characteristic | Definition |
|---|---|
| Name | Dual-touch gesture recognition |
| Description | Dual-touch-recognition is the basis for the recognition of fluid multi-finger gestures to control the user interface of a touch-screen-based application. |
| Mass market deployment | By 2011 |
| Sub category | Multi-touch gesture input |
| Related technology | Multi-touch movement recognition |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Visually impaired users may not be able to identify the area in which touch is recognized<br>- Difficult to use with poor finger control (jitter, low dexterity). |
| Solutions related to accessibility barriers | - Multimodal feedback: enable audio output as additional modality (speaker connector, loudspeaker).<br>- Design UI such that activation of control needs confirmation.<br>- Allow for single-press button input instead of gesture input. |
| Cultural issues | - Possibly hygienic restrictions with public interfaces. |
| Benefit for all users | - Allows "natural" dual-finger gesture recognition. |
| Benefits for older people and people with disabilities | - None identified |
| Deployment pros | - Gesture input is a "natural" interaction modality. |
| Deployment cons | - Risk of un-intentional activation of controls. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.7.5: Resistive multi-touch recognition**

| Characteristic | Definition |
|---|---|
| Name | Resistive multi-touch recognition |
| Description | Resistive multi-touch recognition allows for multi-touch interaction based on resistive recognition technology. |
| Mass market deployment | By 2012 |
| Sub category | Multi touch gesture input |
| Related technology | Dual-touch recognition |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Visually impaired users may not be able to identify the area in which touch is recognized.<br>- People with upper limb impairments may have problems to use this technology. |
| Solutions related to accessibility barriers | - Multimodal feedback: enable audio output as additional modality (speaker connector, loudspeaker).<br>- Design UI such that activation of control needs confirmation.<br>- Allow for single-press button input instead of gesture input. |
| Cultural issues | - Possibly hygienic restrictions with public interfaces. |
| Benefit for all users | - Cost efficient and resilient technology. |
| Benefits for older people and people with disabilities | - Usable by low-dexterity users. |
| Deployment pros | - Works with gloves and various pointing devices. |
| Deployment cons | - Risk of un-intentional activation of controls.<br>- Users with visual impairments cannot detect controls. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.7.6: Multi-touch gesture recognition with various input devices**

| Characteristic | Definition |
|---|---|
| Name | Multi-touch gesture recognition with various input devices |
| Description | Multi-touch gesture recognition with various input devices is based on touch screens which are able to recognize continuous movement from the fingers of two hands or from one hand and pen/digitizer input simultaneously. |
| Mass market deployment | By 2015 |
| Sub category | Multi-touch gesture input |
| Related technology | Multi-touch movement recognition |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Identification of actionable areas may be extremely difficult for visually impaired users.<br>- Gesture language may be difficult to learn and remember. |
| Solutions related to accessibility barriers | - Provide alternate solution based on single-press technology.<br>- Multimodal feedback: enable audio output as additional modality (speaker connector, loudspeaker).<br>- Design UI such that activation of control needs confirmation. |
| Cultural issues | - Possibly hygienic restrictions with public interfaces. |
| Benefit for all users | - Enables design of "natural" gesture-controlled user interfaces. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - Enables design of "natural" gesture-controlled user interfaces. |
| Deployment cons | - Risk of un-intentional activation of controls.<br>- Users with visual impairments may not be able to detect controls or execute gestures.<br>- Difficult to use with poor finger control (jitter).<br>- Visually impaired users cannot recognize contents.<br>- Gestures may be difficult to learn. |
| Implementation requirements | None identified |
| Harmonization | - Gesture language may be subject to harmonization/standardization. |

**Table 6.7.7: Multi-touch movement recognition**

| Characteristic | Definition |
|---|---|
| Name | Multi-touch movement recognition |
| Description | Multi-touch movement recognition is a recognition technology which allows for continuous monitoring of several touch tracks created through the use of two or more fingers. |
| Mass market deployment | By 2015 |
| Sub category | Multi-touch gesture input |
| Related technology | Dual-touch gesture recognition |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Visually impaired users may not be able to identify the area in which touch is recognized.<br>- Users with poor movement control may not be able to use multi-touch input.<br>- Multi-touch input and gestures may be difficult to learn and remember. |
| Solutions related to accessibility barriers | - Provide alternate solution based on single-press technology.<br>- Multimodal feedback: enable audio output as additional modality (speaker connector, loudspeaker).<br>- Design UI such that activation of control needs confirmation. |
| Cultural issues | - Possibly hygienic restrictions with public interfaces. |
| Benefit for all users | - Enables design of "natural" gesture-controlled user interfaces. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - Enables design of "natural" gesture-controlled user interfaces. |
| Deployment cons | - Risk of un-intentional activation of controls.<br>- Users with visual impairments may not be able to detect controls or execute gestures.<br>- Difficult to use with poor finger control (jitter).<br>- Visually impaired users cannot recognize contents.<br>- Gestures may be difficult to learn. |
| Implementation requirements | None identified |
| Harmonization | - Gesture language could be harmonized. |

**Table 6.7.8: Multi touch with hover recognition**

| Characteristic | Definition |
|---|---|
| Name | Multi-touch with hover recognition |
| Description | Multi-touch with hover recognition is the ability of a touch-sensitive display to recognize one or more fingers at a distance of the recognizing surface. This allows for:<br>(i) prediction of touch in several specific areas,<br>(ii) recognition of several exact 3-dimensional coordinates relative to the touch screen with the z-axis being the distance of the digitizer to the surface of the display area, and<br>(iii) the recognition of 3-dimensional multi-point movement. |
| Mass market deployment | By 2015 |
| Sub category | Multi-touch gesture input |
| Related technology | Single touch with hover recognition |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Identification of actionable areas may be extremely difficult for visually impaired users.<br>- People with upper limb impairments may have problems to use this technology |
| Solutions related to accessibility barriers | - Avoid calibrating of the recognizer too susceptible to interference.<br>- Multimodal feedback: enable audio output as additional modality (speaker connector, loudspeaker).<br>- Design UI such that activation of control needs confirmation. |
| Cultural issues | - Possibly hygienic restrictions with public interfaces. |
| Benefit for all users | - Allows natural gesture interfaces with efficient support. |
| Benefits for older people and people with disabilities | - Easier to use for low-dexterity users due to efficient feedback.<br>- Easy to locate (if worn) for visually impaired users. |
| Deployment pros | - Enables easy-to-use touch-screen based gesture recognition interfaces. |
| Deployment cons | - Potentially wrong interpretation and activation of controls based on proximity.<br>- Difficult to use with poor finger control (jitter).<br>- Visually impaired users cannot recognize contents.<br>- Gestures may be difficult to learn. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.7.9: Pressure sensitive touch recognition**

| Characteristic | Definition |
|---|---|
| Name | Pressure sensitive touch recognition |
| Description | Pressure sensitive touch recognition enables UI designers to design user interaction which distinguishes between variable pressure of one or more fingers or digitizers/pens. |
| Mass market deployment | By 2015 |
| Sub category | Multi-touch gesture input |
| Related technology | Pen-based capacitive touch/hover recognition |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Identification of actionable areas may be extremely difficult for visually impaired users. |
| Solutions related to accessibility barriers | - Provide alternate solution based on single-press technology.<br>- Multimodal feedback: enable audio output as additional modality (speaker connector, loudspeaker).<br>- Design UI such that activation of control needs confirmation. |
| Cultural issues | - Possibly hygienic restrictions with public interfaces. |
| Benefit for all users | - High level of control through both gestures and different pressure levels. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - Allow for potentially very flexible touch-based user interaction. |
| Deployment cons | - Risk of un-intentional activation of controls.<br>- Interpretation of different pressure levels and gestures may be difficult to learn.<br>- Users with visual impairments may not be able to detect controls or execute gestures.<br>- Difficult to use with poor finger control (jitter).<br>- Visually impaired users cannot recognize contents. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.7.10: 3-dimensional touch devices**

| Characteristic | Definition |
|---|---|
| Name | 3-dimensional touch devices |
| Description | 3-dimensional touch devices will enable the use of various touch input technologies on a multitude of surfaces of a device. These touch-sensitive areas may be shaped and curved to fit the form factor of the touch sensitive device. |
| Mass market deployment | After 2015 |
| Sub category | Multi-touch gesture input |
| Related technology | All 2-dimensional touch input technologies |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Identification of actionable areas may be extremely difficult for visually impaired users. |
| Solutions related to accessibility barriers | - Provide alternate solution based on 2-dimensional touchscreen technology.<br>- Multimodal feedback: enable audio output as additional modality (speaker connector, loudspeaker).<br>- Design UI such that activation of control needs confirmation. |
| Cultural issues | - Possibly hygienic restrictions with public interfaces. |
| Benefit for all users | - Allows the design of interfaces which are optimized for human hand and finger properties. |
| Benefits for older people and people with disabilities | - Potentially adaptable to specific movement deficiencies. |
| Deployment pros | - Optimally designed UIs for single-hand use possible. |
| Deployment cons | - Risk of un-intentional activation of controls.<br>- Users with visual impairments cannot detect controls.<br>- Difficult to use with poor finger control (jitter). |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.7.11: Pen-based capacitive touch recognition**

| Characteristic | Definition |
|---|---|
| Name | Pen-based capacitive touch recognition |
| Description | Pen-based input - as compared to touch input using a finger - allows for very exact positioning of touch points. Gesture recognition using one (or potentially two pens/digitizers will enable new user interactions including fluent handwriting recognition or complex map manipulation. |
| Mass market deployment | By 2015 |
| Sub category | Pen-based gesture input |
| Related technology | Pen-based capacitive touch/hover recognition |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Identification of actionable areas may be extremely difficult for visually impaired users. |
| Solutions related to accessibility barriers | - Multimodal feedback: implement a user interface design using audio and video.<br>- Allow different interaction using command interface. |
| Cultural issues | - Possibly hygienic restrictions with public interfaces. |
| Benefit for all users | - Allows multi-touch gesture recognition interfaces. |
| Benefits for older people and people with disabilities | - Pen is easier to control by low-dexterity users. |
| Deployment pros | - Offers "natural" gesture input interfaces. |
| Deployment cons | - Users with visual impairments cannot recognize content or controls.<br>- Gestures may be difficult to learn. |
| Implementation requirements | None identified |
| Harmonization | - Gesture language may be subject to harmonization/standardization. |

**Table 6.7.12: Pen-based capacitive touch/hover recognition**

| Characteristic | Definition |
|---|---|
| Name | Pen-based capacitive touch/hover recognition |
| Description | Pen-based capacitive touch/hover recognition recognizes the existence and position of one or more pens and/or fingers before they actually touch the sensitive surface. It is therefore possible:<br>(i) to predict touch in a specific area, and<br>(ii) to recognize exact 3-dimensional coordinates relative to the touch screen with the z-axis being the distance of the digitizer to the surface of the display area. |
| Mass market deployment | By 2015 |
| Sub category | Pen-based gesture input |
| Related technology | Pen-based capacitive touch recognition |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | - Identification of actionable areas may be extremely difficult for visually impaired users.<br>- May be difficult for users with jitter and poor movement control. |
| Solutions related to accessibility barriers | - Multimodal feedback: enable audio output as additional modality (speaker connector, loudspeaker). |
| Cultural issues | - Possibly hygienic restrictions with public interfaces. |
| Benefit for all users | - Allows three-dimensional gesture input. |
| Benefits for older people and people with disabilities | - Easier to use by low-dexterity users.<br>- Allows the implementation of efficient help systems for people with visual impairments. |
| Deployment pros | - Enables easy-to-use touch-screen based button interfaces. |
| Deployment cons | - Potential wrong interpretation and activation of controls based on proximity.<br>- Users with visual impairments cannot recognize content or controls. |
| Implementation requirements | None identified |
| Harmonization | - Gesture language may be subject to harmonization/standardization. |

## 6.8 Visual input technologies roadmap

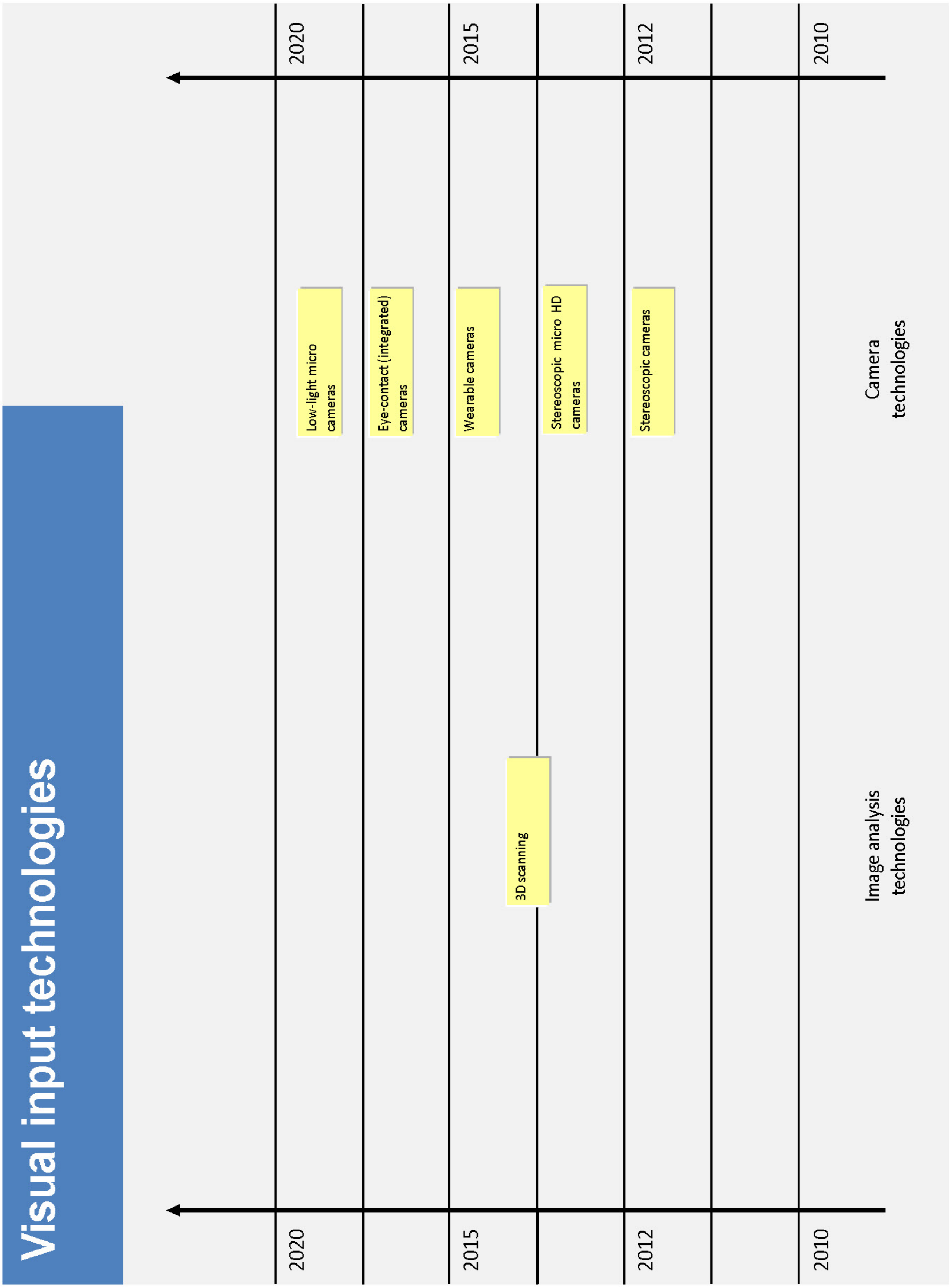


**Figure 6.8.1: Visual input technologies roadmap**

Visual input technologies allow the user to enter visual information about the physical world into ICT. The main areas of innovation in the area of visual input technologies are stereoscopic cameras and miniaturization of cameras. These technologies will support a range of devices, applications and services that require additional interaction. Some of these technologies do not require explicit interaction actions from the user to effect interaction with a service.

Key developments in this area are:

- the ability capture images and video in 3D;
- small form factors enable new devices and services.

The development of visual input technologies will also bring about new accessibility issues:

- all users are not able to perceive 3D;
- the small form factor of these devices will make them difficult to operate for users suffering from motor impairments.

Solutions for these and other accessibility barriers identified for individual or several visual input technologies are listed in the tables 6.8.1 to 6.8.6 and include:

- user limitation compensation: design 3D devices to be able to capture and show 2D;
- low complexity: provide clearly marked controls that are easy to operate.

In most cases the action to input visual information is only performed by a direct order from the user but some visual technologies may be used to constantly analyze information, some could even do so without the user's knowledge. To gain user acceptance it is likely that users will require a clearly indication of the status of the device or service. As the miniaturization, resolution and features of cameras improve more advanced service will probably be linked to them. This development raises privacy issues since new technology may make very advanced cameras difficult to see and even make it possible to see where it was not possible to see before, for example in the dark.

The rapid development of computer power allows for entirely new ways of analysing captured images. With the fast mobile networks emerging today the analysis does not even need to be done on the user device, this lowers demands on both the CPU and battery life of the user device.

Table 6.8.1 gives an alphabetical listing of the technologies covered in this clause.

**Table 6.8.1: Overview of visual input technologies**

| User interaction technology | Sub category | Table |
|---|---|---|
| 3D scanning | Image analysis technologies | 6.8.2 |
| Eye contact (integrated) cameras | Camera technologies | 6.8.6 |
| Low light cameras | Camera technologies | 6.8.7 |
| Stereoscopic cameras | Camera technologies | 6.8.3 |
| Stereoscopic micro HD cameras | Camera technologies | 6.8.4 |
| Wearable cameras | Camera technologies | 6.8.5 |

### Table 6.8.2: 3D scanning

| Characteristic | Definition |
| --- | --- |
| Name | 3D scanning |
| Description | Scanning an object in 3D by using a single camera. Typically by shooting pictures of it from different angles. |
| Mass market deployment | By 2015 |
| Sub category | Image analysis technologies |
| Related technology | None identified |
| User requirements | 01 Perceive visual information<br>13 Understand how to use product<br>14 Understanding the output or displayed material (even after they perceive it accurately) |
| Accessibility barriers | - The procedure for using this technology could be difficult for persons with motor impairments.<br>- Some users are unable to interact with 3D content. |
| Solutions related to accessibility barriers | - Low complexity: provide clear multimodal instructions for use.<br>- Standardized Assistive Device connection: provide interface for assistive devices.<br>- User limitation compensation: design devices to be able to show 2D images of scanned object. |
| Cultural issues | None identified |
| Benefit for all users | - The ability to replicate objects into a digital 3D space. |
| Benefits for older people and people with disabilities | - The ability for blind people to photograph objects that they later wish to 3D print at home to remember. |
| Deployment pros | - Would allow for new product features, new services or improvements to existing services, for example virtual 3D worlds. |
| Deployment cons | - Probably requires off-camera processing.<br>- Photography procedure may be difficult for some users. |
| Implementation requirements | None identified |
| Harmonization | - Several file formats exist, but for mass market introduction, one format needs to become widely supported. |

### Table 6.8.3: Stereoscopic cameras

| Characteristic | Definition |
| --- | --- |
| Name | Stereoscopic cameras |
| Description | Two cameras mounted close together to provide a 3D image. (First consumer camera already released, but no market breakthrough.) |
| Mass market deployment | By 2012 |
| Sub category | Camera technologies |
| Related technology | Stereoscopic micro HD cameras |
| User requirements | 01 Perceive visual information<br>14 Understanding the output or displayed material (even after they perceive it accurately) |
| Accessibility barriers | - Persons not able to perceive 3D will be excluded by devices only able to capture 3D. |
| Solutions related to accessibility barriers | - User limitation compensation: enable camera to also capture 2D images.<br>- Standardized Assistive Device connection: provide interface for assistive devices. |
| Cultural issues | - None identified |
| Benefit for all users | - The possibility to communicate and do documentation in 3D. |
| Benefits for older people and people with disabilities | - Sign-language communication in 3D. |
| Deployment pros | - Stereoscopic consumer cameras are likely to be a strong driver for 3D displays, 3D content and services. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.8.4: Stereoscopic micro HD cameras**

| Characteristic | Definition |
|---|---|
| Name | Stereoscopic micro HD cameras |
| Description | Small stereoscopic camera systems to be mounted in mobile phones, glasses, security systems and so on. |
| Mass market deployment | By 2015 |
| Sub category | Camera technologies |
| Related technology | Stereoscopic cameras |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Persons not able to perceive 3D will be excluded by devices only able to capture 3D.<br>- Due to the small form factor the device could be difficult to operate for persons who are visually impaired or who have motor impairments. |
| Solutions related to accessibility barriers | - User limitation compensation: enable camera to also capture 2D images.<br>- Low complexity: provide clearly marked controls that are easy to operate. |
| Cultural issues | - None identified |
| Benefit for all users | - Highly mobile stereoscopic HD communication and documentation. |
| Benefits for older people and people with disabilities | - Mobile sign-language communication in 3D. |
| Deployment pros | - Mobile stereoscopic cameras allow for a whole range of new services and devices. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.8.5: Wearable cameras**

| Characteristic | Definition |
|---|---|
| Name | Wearable cameras |
| Description | Cameras small enough to worn by the user without inconvenience. May find applications in the smart home and care for dementia patients. |
| Mass market deployment | By 2015 |
| Sub category | Camera technologies |
| Related technology | Stereoscopic micro HD cameras |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>08 Avoid unintentional activation of controls<br>12 Be able to efficiently operate product |
| Accessibility barriers | - Due to the small form factor the device could be difficult to operate for persons who are visually impaired or who have motor impairments. |
| Solutions related to accessibility barriers | - Clear and consistent laws for usage of these devices are needed.<br>- Low complexity: provide clearly marked controls that are easy to operate.<br>- Standardized Assistive Device connection: provide interface for assistive devices. |
| Cultural issues | - Some cultures my strongly oppose consumer cameras that are almost undetectable. |
| Benefit for all users | - The ability to easily document or transmit the current location. |
| Benefits for older people and people with disabilities | - A wearable camera used by a blind user or a dementia patient could be activated when needed. |
| Deployment pros | - Wearable and small cameras could work as cheap sensors that would allow many new services in a wide arrange of areas such as security and entertainment. |
| Deployment cons | - Huge privacy issues. |
| Implementation requirements | None identified |
| Harmonization | - Laws concerning public cameras vary widely across the EU countries. A common agreement would allow citizens to feel secure about their privacy wherever they go. |

### Table 6.8.6: Eye contact (integrated) cameras

| Characteristic | Definition |
|---|---|
| Name | Eye contact (integrated) cameras |
| Description | A camera truly integrated into the screen will provide true eye contact. Could use multiple micro cameras/sensors integrated into the screen fabric or a single camera mounted behind a translucent or switching on/off screen. |
| Mass market deployment | After 2015 |
| Sub category | Camera technologies |
| Related technology | None identified |
| User requirements | 01 Perceive visual information<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any access features needed) |
| Accessibility barriers | - For visually impaired wheelchair users and others it may be hard to position the head in the proper place in front of the screen.<br>- Visually impaired users may have to be very close to the screen to be able to see. This could thwart the eye contact effect. |
| Solutions related to accessibility barriers | - User limitation compensation: if possible make the eye contact point adjustable. |
| Cultural issues | None identified |
| Benefit for all users | - Better eye contact during video-conferencing. |
| Benefits for older people and people with disabilities | - Will also provide better sign-language communication as the user can truly sign to the other person. |
| Deployment pros | - Could improve video conferencing services and products and make video conferencing more widely used. |
| Deployment cons | - Major privacy issues with cameras that can not be seen. |
| Implementation requirements | - Quality of integrated cameras/sensors needs to improve with multiple cameras/sensors.<br>- Form factor decrease for switching/translucent screen with one camera. |
| Harmonization | - Laws concerning public cameras vary widely across the EU countries. A common agreement would allow citizens to feel secure about their privacy wherever they go. |

### Table 6.8.7: Low light cameras

| Characteristic | Definition |
|---|---|
| Name | Low light cameras |
| Description | OLED research indicates the coming of light enhancing and bendable OLEDs. |
| Mass market deployment | After 2015 |
| Sub category | Camera technologies |
| Related technology | Night vision (goggles) |
| User requirements | 01 Perceive visual information |
| Accessibility barriers | - Visually impaired users may experience problems with this technology. |
| Solutions related to accessibility barriers | - Multimodal controls: for visually impaired users to be able to operate the device effectively.<br>- Multimodal feedback: for visually impaired users to be able to operate the device effectively. |
| Cultural issues | None identified |
| Benefit for all users | - Increased range of devices to provide night vision. (Sun-glasses form-factor or possibly windshields). |
| Benefits for older people and people with disabilities | - The ability to communicate in the dark using sign language. |
| Deployment pros | - New products utilizing this technology could change the transport infra structure significantly. More recreational products are likely. |
| Deployment cons | - Some people may feel that their privacy can be invaded more easily. |
| Implementation requirements | - Many obstacles remain, battery life and the light sensitive OLEDs making it into production are the largest. |
| Harmonization | None identified |

## 6.9 Acoustic/audio output technologies roadmap

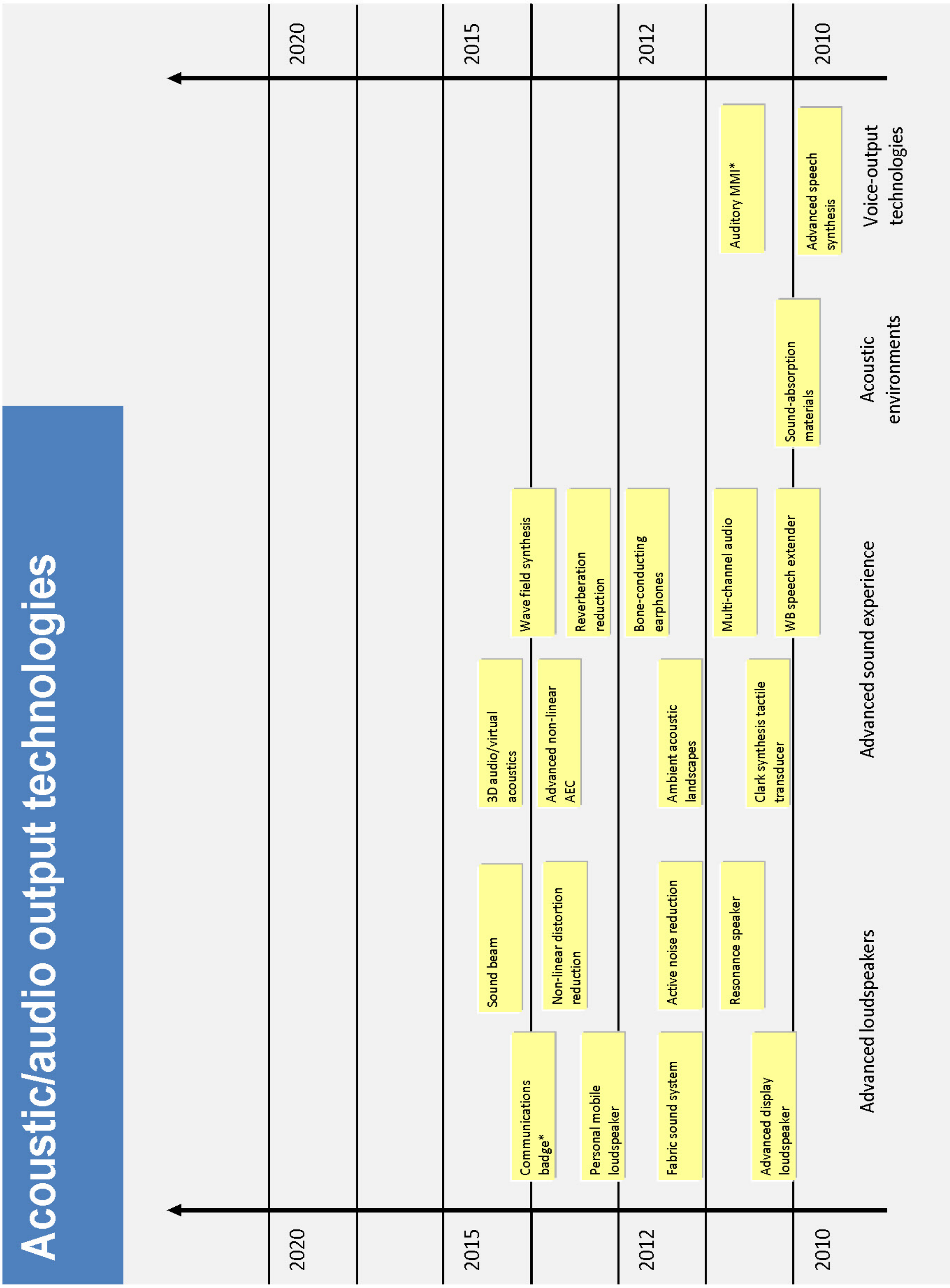


**Figure 6.9.1: Acoustic/audio output technologies roadmap**

The main areas of innovation in the area of acoustic/audio output technologies are advanced loudspeakers, sound experience and voice-output technologies. These technologies will support inter alia the voice interaction with and control of novel eServices.

Key developments in this area are:

- miniaturization and form factors;
- improved sound experience;
- improved privacy;
- improved speech synthesis.

These technologies have the potential to increase accessibility, e.g. by improving the voice control of devices and eServices by visually impaired people. However, they may cause problems for users with severe impairments:

- The upcoming acoustic/audio output technologies may still not work for deaf users and possibly not sufficiently well for severely hard-of-hearing users, e.g. in terms of achievable frequency range and loudness.
- Visually impaired users may find it difficult to identify controls (location of on, off) and indications (status of device, transmitting or idle).

Solutions for these and other accessibility barriers identified for individual or several acoustic/audio output technologies are listed in the tables 6.9.1 to 6.9.18 and include:

- Interfaces for assistive technology devices to compensate for loudness levels and frequency ranges that are inadequate for severely hard-of-hearing people.
- Multimodal controls and indications offering access to a device or eService by means of more than one sensory modality.
- Reduced complexity modes ensuring that important and/or critical functionality (including control of sound characteristics) is easily accessible by all users including those with severe impairments.

NOTE: Some acoustic/audio output technologies listed in figure 6.9.1 with an asterisk next to their names are dealt with in detail in the context of other roadmaps: details of the communications badge and the auditory UI can be found in the context of the roadmap for acoustic/audio input technologies (clause 6.2).

Table 6.9.1 gives an alphabetical listing of the technologies covered in this clause.

**Table 6.9.1: Overview of acoustic/audio output technologies**

| User interaction technology | Sub category | Table |
|---|---|---|
| 3D audio/virtual acoustics | Advanced sound experience | 6.9.17 |
| Active noise reduction | Advanced loudspeakers | 6.9.5 |
| Advanced display loudspeakers | Advanced loudspeakers | 6.9.2 |
| Advanced non-linear acoustic echo cancellation (AEC) | Advanced sound experience | 6.9.15 |
| Advanced speech synthesis | Voice-output technologies | 6.9.19 |
| Ambient acoustic landscapes ("sound scapes") | Advanced sound experience | 6.9.12 |
| Bone-conducting earphones | Advanced sound experience | 6.9.13 |
| Clark synthesis tactile transducer | Advanced sound experience | 6.9.10 |
| Fabric sound system | Advanced loudspeakers | 6.9.4 |
| Multi-channel audio | Advanced sound experience | 6.9.11 |
| Non-linear distortion reduction | Advanced loudspeakers | 6.9.7 |
| Personal mobile loudspeakers | Advanced loudspeakers | 6.9.6 |
| Resonance speakers | Advanced loudspeakers | 6.9.3 |
| Reverberation reduction | Advanced sound experience | 6.9.14 |
| Sound beam | Advanced loudspeakers | 6.9.8 |
| Sound-absorption materials (e.g. textiles) | Acoustic environments | 6.9.18 |
| Wave field synthesis | Advanced sound experience | 6.9.16 |
| Wide-band speech extender | Advanced sound experience | 6.9.9 |

**Table 6.9.2: Advanced display loudspeakers**

| Characteristic | Definition |
|---|---|
| Name | Advanced display loudspeaker |
| Description | Display loudspeakers that surpass present state-of-the-art ones in terms of frequency band and/or loudness. |
| Mass market deployment | By 2012 |
| Sub category | Advanced loudspeakers |
| Related technology | Personal mobile loudspeaker<br>Communications badge |
| User requirements | 02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Frequency range and loudness of advanced display speakers may not be sufficient for severely hard-of-hearing users. |
| Solutions related to accessibility barriers | - Offer controls to adjust sound characteristics.<br>- Offer interface to assistive technologies. |
| Cultural issues | - People in some cultures may not be very tolerant of being disturbed by or overhearing others using a loudspeaker of this type. |
| Benefit for all users | - Can be employed for hands-free sound reproduction.<br>- Allows for very flat and/or watertight implementations. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - New form factors with no visible speaker. |
| Deployment cons | - Advanced display loudspeakers may still be inferior compared to established loudspeaker technologies in terms of frequency bandwidth and loudness.<br>- The limited frequency range may make them difficult to use by elderly or hard-of-hearing users. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.3: Resonance speakers**

| Characteristic | Definition |
|---|---|
| Name | Resonance speaker |
| Description | Device that turns surfaces (e.g. a helmet or cardboard box) into a speaker by using the surface as a resonance body. The advantage is that the sound does not seem to emanate from one specific direction. In addition, it does not close off the listener from other sound sources such as voice or traffic sound. |
| Mass market deployment | By 2012 |
| Sub category | Advanced loudspeakers |
| Related technology | Personal mobile loudspeaker<br>Fabric sound system<br>Advanced display loudspeaker<br>Bone-conducting earphones |
| User requirements | 02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Frequency range and loudness of resonance speakers may not be sufficient for severely hard-of-hearing users. |
| Solutions related to accessibility barriers | - Low complexity: provide low-complexity solution with minimum functionality (e.g. adjust volume, check battery status).<br>- Multimodal controls and multimodal feedback: provide optional mode with audio indications of status feedback (e.g. low battery). |
| Cultural issues | None identified |
| Benefit for all users | - Improved sound experience.<br>- No need to wear earphones or headphones.<br>- Does not close off ambient sounds. |
| Benefits for older people and people with disabilities | - Maybe employed in assistive-technology products for hard-of-hearing people. |
| Deployment pros | - Can be integrated into already existing products such as motorcycle helmets. |
| Deployment cons | - Requires a resonance body of some volume. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.4: Fabric sound system**

| Characteristic | Definition |
|---|---|
| Name | Fabric sound system |
| Description | Wearables and smart clothing is a new trend that combines all sorts of electronics with clothing. An important aspect of wearables is the acoustic interface. Conventional loudspeakers and microphones are not suitable for use in clothing since those components are rigid and relatively thick, heavy and not sufficiently resistant to extreme conditions such as rain, heat or chemicals. New transducer technologies are being developed that can fulfil requirements of wearables. The most promising of those are piezo-electric foils. |
| Mass market deployment | By 2012 |
| Sub category | Advanced loudspeakers |
| Related technology | Personal mobile loudspeaker<br>Resonance speaker<br>Advanced display loudspeaker |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Location and functionality of controls and indications should be easy to recognize and reach by people with disabilities (e.g. visually impaired or mobility impaired users). |
| Solutions related to accessibility barriers | - Low complexity: provide low-complexity solution with minimum functionality (e.g. adjust volume, check battery status).<br>- Multimodal controls and multimodal feedback: provide optional mode with multimodal indications of status feedback (e.g. low battery). |
| Cultural issues | - People in some cultures may be hesitant to use a sound system that allows others to overhear what they are listening to or that may disturb others. |
| Benefit for all users | - All-weather equipment that can be carried easily at all times. |
| Benefits for older people and people with disabilities | - Hands-free equipment that will not be forgotten to bring. |
| Deployment pros | - Allows new outdoor and mobile use cases (both professional and leisure ones). |
| Deployment cons | - Needs to be sturdy and nearly impossible to break.<br>- Needs to connect seamlessly as different systems will be worn on different days. |
| Implementation requirements | - Consider alternative power supplies. |
| Harmonization | None identified |

**Table 6.9.5: Active noise reduction**

| Characteristic | Definition |
|---|---|
| Name | Active noise reduction |
| Description | Active noise reduction is a technology that reduces ambient noise by reproducing 180° phase-shifted components of the sounds that are being reproduced. This has the effect of compensating the sound pressure in the ear originating from the ambient noise by its inverse. Typically, a microphone records the ambient noise components; the signals are then appropriately filtered and delayed. Such technologies are already used as stand-alone systems in headphones e.g. for pilots. |
| Mass market deployment | By 2012 |
| Sub category | Advanced loudspeakers |
| Related technology | Non-linear distortion reduction |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | None identified |
| Solutions related to accessibility barriers | None identified |
| Cultural issues | None identified |
| Benefit for all users | - Improves signal-to-noise ratio. |
| Benefits for older people and people with disabilities | - Significantly improves the quality of service of voice communications for hard-of-hearing people and people with other hearing impairments. |
| Deployment pros | - Does not require expensive hardware components. |
| Deployment cons | - Use cases seem to be limited to wearing earphones or headphones. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.6: Personal mobile loudspeakers**

| Characteristic | Definition |
|---|---|
| Name | Personal mobile loudspeaker |
| Description | A personal loudspeaker that is worn like a brooch or necklace and that is being used for comfortably listening to audio output or for communicating with a person or entity (e.g. a smart home) for longer periods of time. The personal mobile loudspeaker can be combined with a personal mobile microphone to function as a communications badge with input/output functionality. |
| Mass market deployment | By 2015 |
| Sub category | Advanced Loudspeakers |
| Related technology | Personal Mobile Microphone<br>Communications Badge<br>Advanced Display Loudspeaker |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Frequency range and loudness of personal mobile loudspeakers may not be sufficient for severely hard-of-hearing users. |
| Solutions related to accessibility barriers | - Low complexity: provide low-complexity solution with minimum functionality (e.g. adjust volume, check battery status).<br>- Multimodal controls and multimodal feedback: provide optional mode with audio indications of status feedback (e.g. low battery). |
| Cultural issues | - People in some cultures may be concerned about privacy (e.g. being overheard in a public place) and data protection when using such a device.<br>- In some cultures, men will not feel comfortable wearing a device that looks too much like jewellery (e.g. a brooch); therefore, a more neutral alternative with a 'technical' look should be offered as well. |
| Benefit for all users | - Comfortable hands-free communications/entertainment.<br>- Effective solution for interacting with smart environments (smart homes). |
| Benefits for older people and people with disabilities | - Easy to use for mobility impaired or low-dexterity users. |
| Deployment pros | - Offers personal audio-output functionality for interacting with smart environments (e.g. smart home). |
| Deployment cons | - Requires high battery performance to operate for longer periods. |
| Implementation requirements | - Consider alternative power supplies. |
| Harmonization | None identified |

### Table 6.9.7: Non-linear distortion reduction

| Characteristic | Definition |
|---|---|
| Name | Non-linear distortion reduction |
| Description | Non-linear distortions occur at various places in the audio chain in mobile devices. Especially the loudspeaker or receiver causes such distortions when driven at very high amplitudes. Technologies are being developed that compensate and thus reduce non-linear distortions in mobile devices. |
| Mass market deployment | By 2015 |
| Sub category | Advanced loudspeakers |
| Related technology | Active noise reduction<br>Advanced non-linear acoustic echo cancellation (AEC) |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | None identified |
| Solutions related to accessibility barriers | None identified |
| Cultural issues | None identified |
| Benefit for all users | - Improved sound quality for mobile devices. |
| Benefits for older people and people with disabilities | - Potentially improves the quality of service of voice communications for hard-of-hearing people and people with other hearing impairments. |
| Deployment pros | - Possibly implemented in the form of a software solution. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.8: Sound beam**

| Characteristic | Definition |
|---|---|
| Name | Sound beam |
| Description | The sound beam technique allows the generation of sound in the form of a very narrow beam like a flashlight. The sound beam is produced by the so-called parametric array that is used inter alia in the context of underwater sonar. The parametric array exploits the effect of self demodulation caused by the non-linear interaction of sound components. The sound interaction produces new frequencies at summative and difference frequency components. Using an intense ultrasonic carrier and amplitude modulation of the audio signal, a strongly focused audio beam can be generated. With this technique a much narrower beam is generated, as would be possible by physical principles with a transducer of the same aperture. Sending out a collimated beam of low frequency sound would normally require a loudspeaker of several meters in diameter. The ultrasonic transducer needed for the parametric array would in contrast be only several centimetres large. |
| Mass market deployment | By 2015 |
| Sub category | Advanced loudspeakers |
| Related technology | Personal mobile loudspeaker |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy |
| Accessibility barriers | - Area covered by the sound beam may not be obvious and/or accessible to users with disabilities. |
| Solutions related to accessibility barriers | - The presentation area of the sound beam cone should be indicated in a multimodal way (e.g. visually and tactilely).<br>- Very small or very tall people as well as people in wheelchairs should be able to reach the captured area.<br>- Allow users to adjust sound characteristics. |
| Cultural issues | None identified |
| Benefit for all users | - Hands-free sound reproduction (privacy solution).<br>- Multi-language conferencing.<br>- Allowing audio presentation without disturbing others. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - Offers voice-based interfaces in public places while ensuring a maximum level of privacy. |
| Deployment cons | - The spatial area covered by the sound beam is limited and should be indicated (at least in stationary implementations). |
| Implementation requirements | None identified |
| Harmonization | Use of a standardised symbol indicating the presence of a sound-beam-enabled device. |

### Table 6.9.9: Wide-band speech extender

| Characteristic | Definition |
|---|---|
| Name | Wide-band speech extender |
| Description | A system and method for speech-signal enhancement that samples a narrow-band speech signal at a receiver to generate a wide-band speech signal. The lower frequency range of the wide-band speech signal is reproduced using the received narrow-band speech signal. The received narrow-band speech signal is analyzed to determine its formants and pitch information. The upper frequency range of the wideband speech signal is synthesized using information derived from the received narrow-band speech signal. |
| Mass market deployment | By 2012 |
| Sub category | Advanced sound experience |
| Related technology | Active noise reduction<br>Non-linear distortion reduction<br>Advanced nonlinear acoustic echo cancellation (AEC)<br>Reverberation reduction |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | None identified |
| Solutions related to accessibility barriers | None identified |
| Cultural issues | None identified |
| Benefit for all users | - Improved sound quality for voice communications. |
| Benefits for older people and people with disabilities | - Potentially improves the quality of service of voice communications for hard-of-hearing people and people with other hearing impairments. |
| Deployment pros | - Possibly implemented in the form of a software solution. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

### Table 6.9.10: Clark synthesis tactile transducer

| Characteristic | Definition |
|---|---|
| Name | Clark synthesis tactile transducer |
| Description | The Clark synthesis is actually a voice coil similar to those used in traditional speakers. It can be implemented in a case approximately 2 cm across and 0,5 cm high. Instead of coupling the voice coil to a cone that vibrates air, which then vibrates the tympanic membrane of the listener's ear, the Clark Synthesis eliminates the middleman and "shakes" the user directly. Different form factors will allow the implementation in seats or floor joists. |
| Mass market deployment | By 2012 |
| Sub category | Advanced sound experience |
| Related technology | Bone-conducting earphones |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | - Possible side effects for people with specific impairments (e.g. those suffering from epilepsy) are yet to be determined. |
| Solutions related to accessibility barriers | - Test suitability for people with minor or major hearing impairments.<br>- Deliver with appropriate health warnings. |
| Cultural issues | None identified |
| Benefit for all users | - New sound experience and form factors for objects serving as speakers. |
| Benefits for older people and people with disabilities | - Potentially improves the sound quality for hard-of-hearing people and people with other hearing impairments. |
| Deployment pros | - Potentially easy to install.<br>- Offers a novelty effect and potential for movies (e.g. experience of earth quakes). |
| Deployment cons | - May not have a lasting appeal.<br>- May disturb others. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.11: Multi-channel audio**

| Characteristic | Definition |
|---|---|
| Name | Multi-channel audio |
| Description | Multi-channel audio is becoming the standard in entertainments (e.g. movies and games). This allows the user to make selections (e.g. languages and bit rates). |
| Mass market deployment | By 2012 |
| Sub category | Advanced sound experience |
| Related technology | None identified |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product |
| Accessibility barriers | None identified |
| Solutions related to accessibility barriers | - Provide optional mode with audio controls and indications. |
| Cultural issues | None identified |
| Benefit for all users | - Users can select their preferred sound source (e.g. language). |
| Benefits for older people and people with disabilities | This technology can be used to offer special audio channels like voice description (narratives) or explanatory comments. |
| Deployment pros | - Many media formats (e.g. DVD or DVB-S) provide an infrastructure for multi-channel audio.<br>- An increasing number of people appreciate listening to content in the language in which it has been generated and use subtitles for support. |
| Deployment cons | - Contents (e.g. narratives) may be expensive to create, so that some use cases may only be taken up once content can be generated automatically. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.12: Ambient acoustic landscapes ("sound scapes")**

| Characteristic | Definition |
|---|---|
| Name | Ambient acoustic landscapes ("sound scapes") |
| Description | Technology for allowing the user to immerse in acoustic landscapes (e.g. rain forest, beach or big city main street). Source materials are becoming widely available; the immersion experience requires sophisticated sound reproduction. |
| Mass market deployment | By 2012 |
| Sub category | Advanced sound experience |
| Related technology | 3D audio/virtual acoustics<br>Wave field synthesis |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | - Users with various disabilities may have difficulty identifying and operating the controls necessary to adjust the acoustic landscape. |
| Solutions related to accessibility barriers | - User limitation compensation: location and functionality of controls and indications should be easy to recognize and reach by people with disabilities (e.g. visually impaired or mobility impaired users).<br>- Multimodal controls: provide optional mode with audio controls and indications. |
| Cultural issues | - Some sound scapes may be unusual or even offensive to people in some countries.<br>- Sound scapes may be experienced as unwanted attempt to influence the listener. |
| Benefit for all users | - New sound experience enriches ambience of private homes and public places. |
| Benefits for older people and people with disabilities | - Allows mobility impaired and visually impaired people to experience environments that are otherwise possibly closed off to them. |
| Deployment pros | - Available for stationary and mobile implementations.<br>- Many sound sources are already freely available. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.13: Bone-conducting earphones**

| Characteristic | Definition |
|---|---|
| Name | Bone-conducting earphones |
| Description | Bone conduction is the conduction of sound to the inner ear through the bones of the skull. Bone conduction is the reason why a person's voice sounds different to himself/herself when it is recorded and played back. Bone conduction tends to amplify the lower frequencies, and so most people perceive their own voice as being of a lower pitch than others hear it. |
| Mass market deployment | By 2012 |
| Sub category | Advanced sound experience |
| Related technology | Active noise reduction |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | - Possible side effects for people with specific impairments (e.g. those suffering from epilepsy) are yet to be determined. |
| Solutions related to accessibility barriers | - Test suitability for people with minor or major impairments.<br>- Deliver with appropriate health warnings. |
| Cultural issues | None identified |
| Benefit for all users | - Allows new form factors (other than earphones or headphones). |
| Benefits for older people and people with disabilities | - Improves sound presentation for hard-of-hearing people and people with other hearing impairments. |
| Deployment pros | - Allows listening to one source while having the ears free for stimuli from the surroundings. |
| Deployment cons | - May be difficult to get used to.<br>- May not appeal to the majority of customers. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.14: Reverberation reduction**

| Characteristic | Definition |
|---|---|
| Name | Reverberation reduction |
| Description | Hands-free communication quality is impaired not only by ambient noise but also by reverberation. Reverberation is caused by multi-path propagation of the acoustic signal producing early and late arriving (diffuse) reflections. The sound travels not only directly from a mouth to a microphone but also over indirect reflections paths, e.g. over the walls of a room. The reverberation time is usually in the range of several 100 ms to 1 000 ms (from car to big rooms). The superimposing of reverberation to the direct signal causes smearing of the speech signal, making it less intelligible. In addition the speaker sounds metallic (as if it was in a tin). Reverberation reduction and decolouration methods can increase hands-free sound quality and speech intelligibility. |
| Mass market deployment | By 2015 |
| Sub category | Advanced sound experience |
| Related technology | Active noise reduction<br>Non-linear distortion reduction<br>Advanced nonlinear acoustic echo cancellation (AEC) |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | None identified |
| Solutions related to accessibility barriers | None identified |
| Cultural issues | None identified |
| Benefit for all users | - Improved sound quality for voice communications. |
| Benefits for older people and people with disabilities | - Potentially improves the quality of service of voice communications for hard-of-hearing people and people with other hearing impairments. |
| Deployment pros | - Possibly implemented in the form of a software solution. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.15: Advanced non-linear acoustic echo cancellation (AEC)**

| Characteristic | Definition |
|---|---|
| Name | Advanced non-linear acoustic echo cancellation (AEC) |
| Description | A range of acoustic echo cancellation techniques (AEC) that are used to approximate the experience of a true full-duplex speech solution. |
| Mass market deployment | By 2015 |
| Sub category | Advanced sound experience |
| Related technology | Active noise reduction |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | None identified |
| Solutions related to accessibility barriers | None identified |
| Cultural issues | None identified |
| Benefit for all users | - Improves quality two-way full-duplex voice communication (e.g. with both parties using hands free). |
| Benefits for older people and people with disabilities | - Significantly improves the quality of service of voice communications for hard-of-hearing people and people with other hearing impairments. |
| Deployment pros | - Software solution requiring little extra hardware components. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.16: Wave field synthesis**

| Characteristic | Definition |
|---|---|
| Name | Wave field synthesis |
| Description | Wave field synthesis (WFS) is a spatial audio rendering technique, characterized by the creation of virtual acoustic environments. It produces "artificial" wave fronts synthesized by a large number of individually driven speakers. Such wave fronts seem to originate from a virtual starting point, the virtual source or notional source. Contrary to traditional spatialization techniques such as stereo, the localization of virtual sources in WFS does not depend on or change with the listener's position. |
| Mass market deployment | By 2015 |
| Sub category | Advanced sound experience |
| Related technology | 3D audio/virtual acoustics<br>Ambient acoustic landscapes |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | - Possible side effects for people with specific impairments (e.g. those suffering from epilepsy) are yet to be determined. |
| Solutions related to accessibility barriers | - Test suitability for people with minor or major impairments.<br>- If necessary, deliver with appropriate health warnings. |
| Cultural issues | None identified |
| Benefit for all users | - New sound experience (corresponds to the currently popular 3D movies). |
| Benefits for older people and people with disabilities | - Allows mobility impaired and visually impaired people to experience environments that are otherwise possibly closed off to them. |
| Deployment pros | - May initially be a differentiator for premium movie theatres. |
| Deployment cons | - Will initially be very expensive to implement. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.17: 3D audio/virtual acoustics**

| Characteristic | Definition |
|---|---|
| Name | 3D audio/virtual acoustics |
| Description | 3D audio or virtual acoustics allows listeners to feel that they are present in an environment that is different from the one in which they are physically present e.g. the listener immerses acoustically into a music concert or into a game. Applying 3D audio the sound perception enters a new dimension. Sound sources can be placed at any point in the virtual environment and even be moved around. With multi-channel audio in consumer audio, 3D audio especially with headphone listening will become standard in mobile devices.<br>3D audio requires head-related transfer function (HRTF) and reverberation simulation processing. In the case of headphone listening, head-tracking exceptionally improves spatial perception. In the case of loudspeaker sound reproduction, cross-talk cancellation has to be used. Multi-channel input is not necessarily required for 3D sound reproduction. Very good results are achieved even with stereo input and the simulation of typical listening rooms (concert hall, club, living room). |
| Mass market deployment | By 2015 |
| Sub category | Advanced sound experience |
| Related technology | Ambient acoustic landscapes<br>Wave field synthesis |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | - Possible side effects for people with specific impairments (e.g. those suffering from epilepsy oh those who can hear with one ear only) are yet to be determined.<br>- Restricted effect for people who can only hear with one ear. |
| Solutions related to accessibility barriers | - Multimodal controls and multimodal feedback: provide optional mode with audio controls and indications.<br>- Test suitability for people with minor or major impairments.<br>- If necessary, deliver with appropriate health warnings. |
| Cultural issues | None identified |
| Benefit for all users | - New sound experience (corresponds to the currently popular 3D movies). |
| Benefits for older people and people with disabilities | - Allows mobility impaired and visually impaired people to experience environments that are otherwise possibly closed off to them. |
| Deployment pros | - Available for stationary and mobile implementations.<br>- May quickly become state of the art. |
| Deployment cons | - Needs near-to-perfect HRTF.<br>- May cause nausea. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.18: Sound-absorption materials (e.g. textiles)**

| Characteristic | Definition |
|---|---|
| Name | Sound-absorption materials (e.g. textiles) |
| Description | Materials for creating surfaces that absorb sound (panels that promote a feeling of positive acoustic comfort whilst controlling and regulating reflected sound and making speech and music more intelligible). These can reach the highest possible absorption class. |
| Mass market deployment | By 2012 |
| Sub category | Acoustic environments |
| Related technology | Fabric sound system<br>Active noise reduction |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | None identified |
| Solutions related to accessibility barriers | None identified |
| Cultural issues | None identified |
| Benefit for all users | - Improves signal-to-noise ratio. |
| Benefits for older people and people with disabilities | - Significantly improves the quality of service of voice communications for hard-of-hearing people and people with other hearing impairments. |
| Deployment pros | - Can be installed in public places (e.g. in phone booths) and private environments. |
| Deployment cons | None identified |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.9.19: Advanced speech synthesis**

| Characteristic | Definition |
|---|---|
| Name | Advanced speech synthesis |
| Description | Speech synthesis is the artificial production of human speech. A computer system used for this purpose is called a speech synthesizer, and can be implemented in software or hardware. A text-to-speech (TTS) system converts normal language text into speech; other systems render symbolic linguistic representations like phonetic transcriptions into speech. Synthesized speech can be created by concatenating pieces of recorded speech that are stored in a database. Systems differ in the size of the stored speech units; a system that stores phones or diphones provides the largest output range, but may lack clarity. For specific usage domains, the storage of entire words or sentences allows for high-quality output. Alternatively, a synthesizer can incorporate a model of the vocal tract and other human voice characteristics to create a completely "synthetic" voice output. The challenge for advanced Speech Synthesis systems is to reproduce human speech to a qualitative level that makes it difficult or even impossible for a human listener to determine whether the speech has been uttered by a human or a machine. This includes inter alia the consideration of prosodics and emotional contents e.g. to determine whether a "speaker" is smiling. Some people argue that it should always be possible for the listener to determine whether speech is uttered by a person or by a machine. |
| Mass market deployment | By 2012 |
| Sub category | Voice-output technologies |
| Related technology | Speech recognition<br>Distributed speech recognition<br>Audio-visual speech recognition<br>Intelligent word spotting |
| User requirements | 02 Perceive auditory information |
| Accessibility barriers | - People with hearing impairments and possibly those with cognitive impairments may need vocal information to be presented redundantly through text. |
| Solutions related to accessibility barriers | - Allow users to adjust sound characteristics.<br>- Provide interface for assistive devices.<br>- Multimodal presentation: ensure that output can also be represented as text. |
| Cultural issues | - People are very sensitive to national and regional accents some of which may not be well received in some countries. |
| Benefit for all users | - Offers inexpensive audio text output. |
| Benefits for older people and people with disabilities | - High-quality implementation presents an acceptable replacement of spoken (by a human) text for visually impaired people. |
| Deployment pros | - Easy to implement in mobile devices. |
| Deployment cons | - Needs to be much better than today's state of the art in terms of intelligent modulation, otherwise very tiresome to listen to. |
| Implementation requirements | None identified |
| Harmonization | None identified |

## 6.10 Haptic/tactile output technologies roadmap

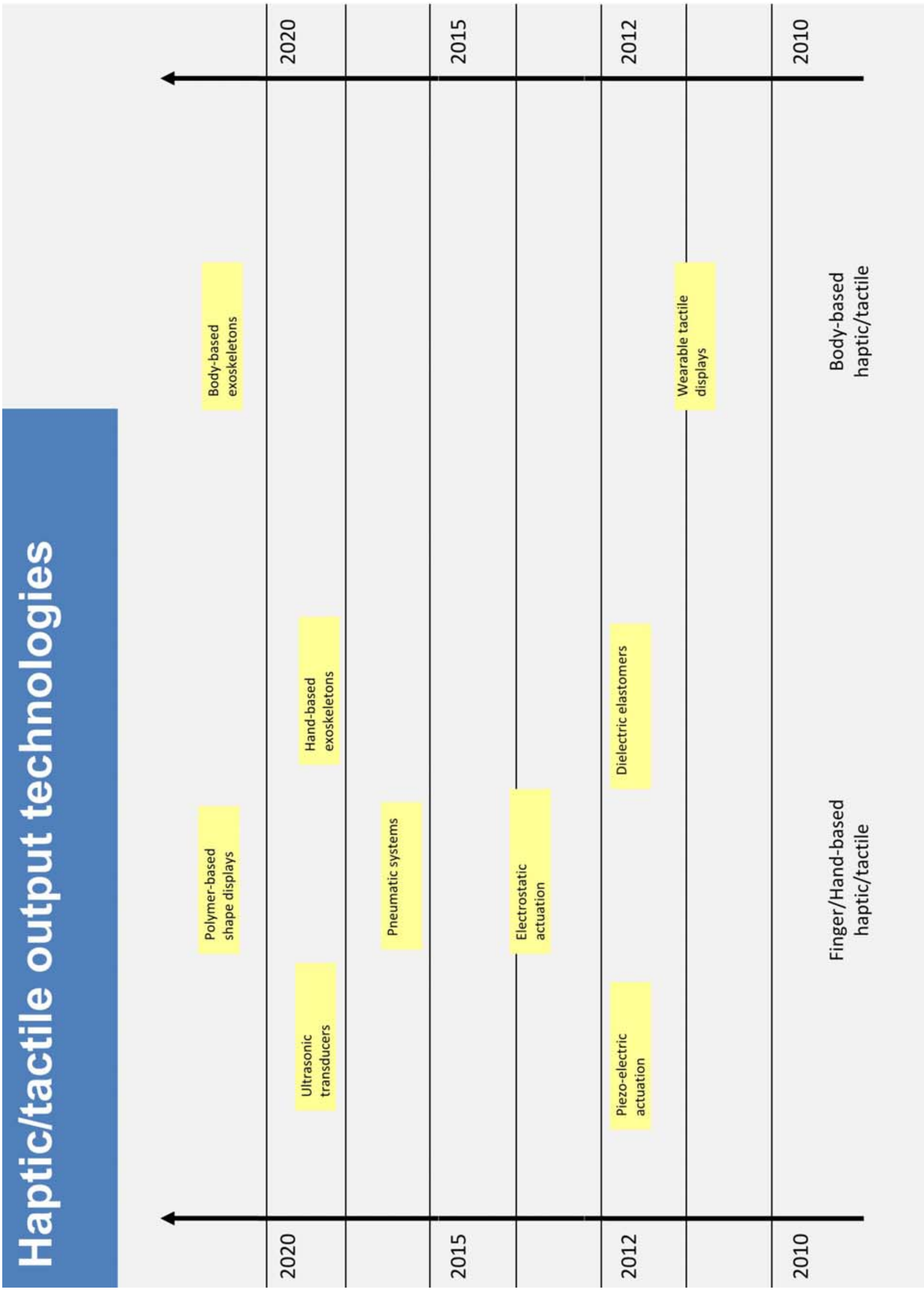


**Figure 6.10.1: Haptic/tactile output technologies roadmap**

There is an increasing interest in integrating the sense of touch in user interfaces. Touch senses objects that are in contact with the body (therefore it may be used for improving confidentiality of the communication), it is bidirectional (i.e. it supports both output and input communication with computers), and it allows notification of information to users even when they are concentrated on other tasks. Furthermore, the skin presents several affordances when used in perceiving computer output, including: its ability to make spatial and temporal discrimination, the effectiveness of cutaneous sensations for capturing user's attention, as well as the large area it offers for potential stimulation [Jones & Sarter, 2008]. Regarding the use the sense for perceiving system's output, some authors recommend the following use of the terms haptic and tactile [Wunschmann & Fourney, 2005]:

- haptic should be used in cases of passive perception only. Passive perception means that no motor actions with the purpose of getting the haptic information are involved;
- tactile should be used in cases of human activities (interactions), based on haptic perception, in combination with purpose oriented (goal driven) motor actions.

Classification in subcategories within this haptic/tactile output clause has been designed according to the part/s of the human body involved in the interaction, namely Finger/Hand-based and Body-based haptic/tactile interactions.

Haptic/tactile output can be used for various purposes in user interfaces, including: Providing an alternative or complement to visual and/or audio outputs in order to improve efficiency, effectiveness and/or satisfaction (e.g. vibration of a mobile phone, wearable tactile orientation support system, haptic/tactile feedback on touchscreens); Presenting genuine haptic/tactile information (object shape, roughness, softness, friction, etc.); Supporting users' immersion in virtual environments.

Main accessibility barriers for using these technologies have to do with perceiving and understanding haptic/tactile output, especially when the signal is complex (e.g. objects' shapes or surfaces; complex symbols), when users are not familiarized with how the system encodes output information, or when insufficient haptic/tactile information is provided as an alternative to other output modalities; Tactile interaction interfering with other input or output modalities; Heavy or uncomfortable wearable devices.

Solutions to these barriers include consistent integration of haptic/tactile output with other interaction modalities (e.g. audio, visual, kinaesthetic); Optimising haptic/tactile rendering characteristics (e.g. locus of stimuli, amplitude, duration and rhythm of the signal), and allowing users to control them; Enabling users to perceive haptic/tactile information without accidentally activating system's controls (e.g. by touch, kinaesthetic input, gesture recognition); Using haptic/tactile patterns users are familiarized with; Allowing users to adjust the size of presented tactile objects, as well as to navigate among them; Producing portable, silent and fashionable wearable haptic/tactile devices.

People considering the use of haptic/tactile output technologies in ICT devices and services can find additional useful insights and information in the following sources: [Jones & Sarter, 2008], [Wunschmann & Fourney, 2005], [ISO 9241-920], [Hong & Pentland, 2001], [Rantala et al, 2009] (generic guidance on haptic and tactile interaction with ICT products and services); [Laycock & Day, 2003] (onscreen tactile feedback); [Hoshi, Iwamoto & Shinoda, 2009] (ultrasonic transducers); [Bolzmacher et al, 2004] (application of polymers to haptic/tactile output); [Vertegaal & Poupyrev, 2008] (object shape displays); [Herr, 2009], [Ferris, 2009] (exoskeletons).

Table 6.10.1 gives an alphabetical listing of the technologies covered in this clause.

**Table 6.10.1: Overview of haptic/tactile output technologies**

| User interaction technology | Sub category | Table |
|---|---|---|
| Body-based exoskeletons | Body-based haptic/tactile | 6.10.10 |
| Dielectric elastomers | Finger/hand-based haptic/tactile | 6.10.3 |
| Electrostatic actuation | Finger/hand-based haptic/tactile | 6.10.4 |
| Hand-based exoskeletons | Finger/hand-based haptic/tactile | 6.10.7 |
| Piezo-electric actuation | Finger/hand-based haptic/tactile | 6.10.2 |
| Pneumatic systems | Finger/hand-based haptic/tactile | 6.10.5 |
| Polymer-based shape displays | Finger/hand-based haptic/tactile | 6.10.8 |
| Ultrasonic transducers | Finger/hand-based haptic/tactile | 6.10.6 |
| Wearable tactile displays | Body-based haptic/tactile | 6.10.9 |

**Table 6.10.2: Piezo-electric actuation**

| Characteristic | Definition |
|---|---|
| Name | Piezo-electric actuation |
| Description | Haptic output is generated by piezoelectric actuators, i.e. ceramic materials that expand/bend when a voltage is applied. They do this at high speed, which means piezoelectric actuators can respond quickly when the haptic display (e.g. a screen) is being touched. The slight movement is felt by a finger touching the screen. The user experiences it as if the screen had relief. This technology enables the display of haptic/tactile information on touchscreens. |
| Mass market deployment | By 2012 |
| Sub category | Finger/hand-based haptic/tactile |
| Related technology | Dielectric elastomer actuators<br>Electrostatic actuation<br>Pneumatic systems<br>Ultrasonic transducers |
| User requirements | 03 Perceive existence and location of actionable components<br>05 Perceive status of controls and indicators<br>08 Avoiding unintentional activation of controls<br>17 Perceive tactile/haptic information |
| Accessibility barriers | - When locating the "raised" information, buttons or controls there is a risk that any touch activated controls may be accidentally activated.<br>- There is also a risk that users may confuse those "raised" areas intended to convey information, or non-actionable elements (e.g. logos, decorative details) with buttons or controls, or vice versa.<br>- When symbolic/graphical information that may be easy to perceive visually is presented as tactile/haptic feedback or information, it may be difficult to perceive. |
| Solutions related to accessibility barriers | - Multimodal presentation: Visual or auditory alternatives should be provided for all haptic/tactile information.<br>- Multimodal control: Visual and/or tactile landmarks and cues should be provided to enable users to quickly re-find all keys and controls during use (e.g. making the digit at the centre of a virtual dial pad feel as if it stands out more than the other keys).<br>- Multimodal control: Mechanisms should be provided that allow all buttons and controls to be located and identified by non-visual means without activating them (e.g. an alternative non-visual interface control mechanism that fully duplicates the control location/activation functionality could be provided).<br>- Multimodal control: Non-actionable elements (e.g. logos, decorative details) should be presented in ways that make them very distinct from buttons and controls, both visually and when sensed via tactile or haptic means.<br>- Symbolic/graphical information intended to be presented for tactile/haptic identification should be designed so that it can be clearly identified by the tactile/haptic senses.<br>- A combination of different encoding schemas (e.g. amplitude, spatio-temporal, rhythm) may be required in order to optimise user's perception. |
| Cultural issues | None identified |
| Benefit for all users | - It may offer an alternative/complement to visual and acoustic information displayed by the system.<br>- When used in touchscreens, it increases satisfaction and performance for users entering information through virtual keyboards. This method expands the variability of the tactile stimuli enabling much more freedom for haptic stimuli design compared to vibration motors.<br>- It may be used for producing genuine haptic output, e.g. simulating surface properties like texture, roughness, etc. |
| Benefits for older people and people with disabilities | - It supports alternative output to visual and acoustic information, when sight or hearing can not be used while operating the device.<br>- It may increase the accessibility of on-screen keyboards to visually impaired users.<br>- This technology may support the display of Braille characters on mobile devices with no additional displays attached to them. |
| Deployment pros | - It is particularly useful for applications in which only motion of the touch screen is desired and not vibration of the entire device.<br>- It allows high bandwidth, making high fidelity touch feedback possible. It also allows fast response time, which also leads to reduced power consumption. |

| Characteristic | Definition |
|---|---|
| Deployment cons | - When used for virtual on-screen keyboards, this technology currently can only produce basic sensations that mimic the different stages of pressing a physical button (e.g. pushing down, letting it go).<br>- High voltages are required to actuate the piezoelectric elements (from the tens to hundreds of volts).<br>- Piezo-electric actuators are fragile due to the fact they are ceramic. |
| Implementation requirements | - Allowing hi-fi haptic/tactile output requires very fine arrays of tactile stimulators. Advancement in this line of research will also bring more sophisticated haptic output. |
| Harmonization | - These displays should adhere to available standards on accessibility of haptic/tactile interactions.<br>- Devices where screen is used as an output and input component should adhere to standards on hardware and software accessibility. |

**Table 6.10.3: Dielectric elastomers**

| Characteristic | Definition |
|---|---|
| Name | Dielectric elastomers |
| Description | Voltage causes deformations of the elastomer. After the stimulation has finished, the elastomer goes back to its original position.<br>This technology enables the display of haptic/tactile information on touchscreens. |
| Mass market deployment | By 2012 |
| Sub category | Finger/hand-based haptic/tactile |
| Related technology | Piezo-electric actuation<br>Electrostatic actuation<br>Pneumatic systems<br>Ultrasonic transducers |
| User requirements | 03 Perceive existence and location of actionable components<br>05 Perceive status of controls and indicators<br>08 Avoiding unintentional activation of controls<br>17 Perceive tactile/haptic information |
| Accessibility barriers | - When locating the "raised" information, buttons or controls there is a risk that any touch activated controls may be accidentally activated.<br>- There is also a risk that users may confuse those "raised" areas intended to convey information, or non-actionable elements (e.g. logos, decorative details) with buttons or controls, or vice versa.<br>- When symbolic/graphical information that may be easy to perceive visually is presented as tactile/haptic feedback or information it may be difficult to perceive. |
| Solutions related to accessibility barriers | - Multimodal presentation: Visual or auditory alternatives should be provided for all haptic/tactile information.<br>- Multimodal control: Visual and/or tactile landmarks and cues should be provided to enable users to quickly re-find all keys and controls during use (e.g. making the digit at the centre of a virtual dial pad feel as if it stands out more than the other keys).<br>- Multimodal control: Mechanisms should be provided that allow all buttons and controls to be located and identified by non-visual means without activating them (e.g. an alternative non-visual interface control mechanism that fully duplicates the control location/activation functionality could be provided).<br>- Multimodal control: Non-actionable elements (e.g. logos, decorative details) should be presented in ways that make them very distinct from buttons and controls, both visually and when sensed via tactile or haptic means.<br>- Symbolic/graphical information intended to be presented for tactile/haptic identification should be designed so that it can be clearly identified by the tactile/haptic senses.<br>- A combination of different encoding schemas (e.g. amplitude, spatio-temporal, rhythm) may be required in order to optimise user's perception. |
| Cultural issues | None identified |
| Benefits of all users: | - It may offer an alternative/complement to visual and acoustic information displayed by the system.<br>- When used in touchscreens, it increases satisfaction and performance for users entering information through virtual keyboards.<br>- It may be used for producing genuine haptic output, e.g. simulating surface properties like texture, roughness, etc. |

| Characteristic | Definition |
|---|---|
| Benefits for older people and people with disabilities | - It offers an alternative to visual and acoustic information, when sight or hearing can not be used while operating the device.<br>- It may increase the accessibility of on-screen keyboards to visually impaired users. |
| Deployment pros | - This technology requires less power compared to traditional vibration motors and piezo-actuators. |
| Deployment cons | - When used for virtual on-screen keyboards, this technology currently can only produce basic sensations that mimic the different stages of pressing a physical button (e.g. pushing down, letting it go).<br>- This technology requires application of high voltages. |
| Implementation requirements | - Allowing accessible haptic/tactile on-screen interaction requires improving the resolution and fidelity of on-screen displayed haptics. Advancement on this line of research will also bring more sophisticated haptic output (e.g. the sensation of textures on a screen).<br>- Display of high fidelity haptic/tactile information will require very fine arrays of tactile stimulators. Polymers should permit to be deposited in thin films and stacked in a multi-layer configuration, allowing the miniaturization of the actuators.<br>- The main challenge today in dielectric polymer technology is to reduce the high voltages required to drive them. |
| Harmonization | - These displays should adhere to available standards on accessibility of haptic/tactile interactions.<br>- Devices where screen is used as an interaction (output+input) component should adhere to standards on hardware and software accessibility, including accessibility to keypads and keyboards. |

### Table 6.10.4: Electrostatic actuation

| Characteristic | Definition |
|---|---|
| Name | Electrostatic actuation |
| Description | Haptic touch technology based on the concept of surface actuation which uses the principle of electrostatic attraction. When the surface is touched, the controller generates a charge differential between the touch surface and the sub-surface, causing the motion of the touch surface.<br>This technology enables the display of haptic/tactile information on touchscreens. |
| Mass market deployment | By 2015 |
| Sub category | Finger/hand-based haptic/tactile |
| Related technology | Piezo-electric actuation<br>Dielectric elastomers<br>Pneumatic systems<br>Ultrasonic transducers |
| User requirements | 03 Perceive existence and location of actionable components<br>05 Perceive status of controls and indicators<br>08 Avoiding unintentional activation of controls<br>- 17 Perceive tactile/haptic information |
| Accessibility barriers | - In order to detect "raised" features generated by movement of the touch surface, the haptic/tactile sense has to be used. When locating the information, buttons or controls there is a risk that any touch activated controls may be accidentally activated.<br>- There is also a risk that users may confuse those "raised" areas intended to convey information, or non-actionable elements (e.g. logos, decorative details) with buttons or controls, or vice versa.<br>- When symbolic/graphical information that may be easy to perceive visually is presented as tactile/haptic feedback or information it may be difficult to perceive. |

| Characteristic | Definition |
|---|---|
| Solutions related to accessibility barriers | - Multimodal presentation: Visual or auditory alternatives should be provided for all haptic/tactile information.<br>- Multimodal control: Visual and/or tactile landmarks and cues should be provided to enable users to quickly re-find all keys and controls during use (e.g. making the digit at the centre of a virtual dial pad feel as if it stands out more than the other keys).<br>- Multimodal control: Mechanisms should be provided that allow all buttons and controls to be located and identified by non-visual means without activating them (e.g. an alternative non-visual interface control mechanism that fully duplicates the control location/activation functionality could be provided).<br>- Multimodal control: Non-actionable elements (e.g. logos, decorative details) should be presented in ways that make them very distinct from buttons and controls, both visually and when sensed via tactile or haptic means.<br>- Symbolic/graphical information intended to be presented for tactile/haptic identification should be designed so that it can be clearly identified by the tactile/haptic senses (this may require this information to be much less detailed than would be acceptable for its visual only equivalent). |
| Cultural issues | None identified |
| Benefits of all users: | - It may offer an alternative/complement to visual and acoustic information displayed by the system.<br>- It increases satisfaction and performance for users entering information through on-screen keyboards.<br>- It may be used for producing genuine haptic output, e.g. simulating surface properties like texture, roughness, etc. |
| Benefits for older people and people with disabilities | - It offers an alternative to visual and acoustic information, when sight or hearing can not be used while operating the device.<br>- It may increase the accessibility of on-screen keyboards to visually impaired users. |
| Deployment pros | - This technology does not depend on discrete actuators; therefore it is easier to achieve a consistent response profile over the entire touch surface.<br>- The actuation force scales with the touch surface area, which makes surface actuation more compelling as the touch-screen area increases.<br>- This technology offers higher reliability, because of mechanical simplicity.<br>- Power consumption is low. |
| Deployment cons | - High voltages are still required to stimulate the film.<br>- This technology currently can only produce basic sensations that mimic the different stages of pressing a physical button (e.g. pushing down, letting it go). |
| Implementation requirements | - When used for displaying on-screen haptic/tactile information, this technology currently can only produce basic sensations that mimic the different stages of pressing a physical button (e.g. pushing down, letting it go). |
| Harmonization | - These displays should adhere to available standards on accessibility of haptic/tactile interactions.<br>- Devices where screen is used as an interaction (output+input) component should adhere to standards on hardware and software accessibility, including accessibility to keypads and keyboards. On the other hand, standards on generic ICT accessibility should develop further aspects about haptic/tactile interaction. |

**Table 6.10.5: Pneumatic systems**

| Characteristic | Definition |
|---|---|
| Name | Pneumatic systems |
| Description | Tactile stimulation by using air jets, air pockets or air rings. Air jets may be used to implement contactless haptic/tactile output. |
| Mass market deployment | After 2015 |
| Sub category | Finger/hand-based haptic/tactile |
| Related technology | Piezo-electric actuation<br>Dielectric elastomers<br>Electrostatic actuation<br>Ultrasonic transducers |
| User requirements | 03 Perceive existence and location of actionable components.<br>05 Perceive status of controls and indicators.<br>06 Be able to invoke and carry out all actions including maintenance and setup<br>08 Avoiding unintentional activation of controls.<br>11 Not cause personal risk<br>17 Perceive tactile/haptic information |

| Characteristic | Definition |
|---|---|
| Accessibility barriers | - In order to detect the stimulation, the haptic/tactile sense has to be used. When locating the information, buttons or controls there is a risk that any touch/kinaesthetic activated controls may be accidentally activated.<br>- There is a danger that if the pressures used are too great or too small the ability to correctly sense and activate the "raised" features will be impaired.<br>- These systems may require bulky parts (air compressor or motor-driven pistons), and therefore these systems are not really portable currently.<br>- There is also a risk that users may confuse those "raised" areas intended to convey information, or non-actionable elements (e.g. logos, decorative details) with buttons or controls, or vice versa.<br>- When liquids are used, safety issues should be addressed. Air jet based actuators tend to be much safer but the force they can produce is limited.<br>- When symbolic/graphical information that may be easy to perceive visually is presented as tactile/haptic feedback or information it may be difficult to perceive. |
| Solutions related to accessibility barriers | - Air jet actuators should produce the necessary levels of pressure. Pressure produced should meet human's ability to sense pressure, just above 0.2 N/cm2. Large pressure levels deteriorate the sensing ability.<br>- Multimodal presentation: Visual or auditory alternatives should be provided for all haptic/tactile information.<br>- Multimodal control: Visual and/or tactile landmarks and cues should be provided to enable users to quickly re-find all keys and controls during use (e.g. making the digit at the centre of a virtual dial pad feel as if it stands out more than the other keys).<br>- Multimodal control: Mechanisms should be provided that allow all buttons and controls to be located and identified by non-visual means without activating them (e.g. an alternative non-visual interface control mechanism that fully duplicates the control location/activation functionality could be provided).<br>- Multimodal control: Non-actionable elements (e.g. logos, decorative details) should be presented in ways that make them very distinct from buttons and controls, both visually and when sensed via tactile or haptic means.<br>- Symbolic/graphical information intended to be presented for tactile/haptic identification should be designed so that it can be clearly identified by the tactile/haptic senses (this may require this information to be much less detailed than would be acceptable for its visual only equivalent). |
| Cultural issues | None identified |
| Benefits of all users: | - It may offer an alternative/complement to visual and acoustic information displayed by the system.<br>- It may increase satisfaction and performance for users entering information through on-screen keyboards. |
| Benefits for older people and people with disabilities | - It may offer an alternative to visual and acoustic information, when sight or hearing can not be used while operating the device.<br>- It may increase the accessibility of on-screen keyboards to visually impaired users. |
| Deployment pros | - Air jet based displays can be used to create contactless haptic/tactile output. |
| Deployment cons | - It may require bulky parts.<br>- Also, they can be very noisy and have limitations to display sharp edges or discontinuities.<br>- When liquids are used, safety issues should be addressed. Air jet based actuators tend to be much safer but the force they can produce is limited.<br>- Air jet based displays have limited spatial and temporal properties which limit the resolution of haptic/tactile information. |
| Implementation requirements | - Weight of equipment should be reduced.<br>- Healthy and safety issues need to be addressed.<br>- Resolution of the rendered information should be improved.<br>- Pressure produced by air jets should be enough to be perceived by users. |
| Harmonization | - These displays should adhere to available standards on accessibility of haptic/tactile interactions.<br>- Devices where screen is used as an interaction (output+input) component should adhere to standards on hardware and software accessibility, including accessibility to keypads and keyboards. |

**Table 6.10.6: Ultrasonic transducers**

| Characteristic | Definition |
| --- | --- |
| Name | Ultrasonic transducers |
| Description | Contactless haptic/tactile output based on acoustic radiation pressure, which is a non-linear phenomenon of ultrasound. Ultrasonic displays are usually composed of a certain number of airborne ultrasound transducers, whose phase and intensity are controlled individually. When combined with mid-air and/or 3D stereoscopic displays, this device provides high-fidelity tactile feedback for interaction with visual objects. |
| Mass market deployment | After 2015 |
| Sub category | Finger/hand-based haptic/tactile |
| Related technology | Piezo-electric actuation<br>Dielectric elastomers<br>Electrostatic actuation<br>Pneumatic systems |
| User requirements | 03 Perceive existence and location of actionable components<br>05 Perceive status of controls and indicators<br>08 Avoiding unintentional activation of controls<br>17 Perceive tactile/haptic information |
| Accessibility barriers | - In order to detect the stimulation, the haptic/tactile sense has to be used. When locating the information, buttons or controls there is a risk that any touch/kinaesthetic activated controls may be accidentally activated.<br>- When symbolic/graphical information that may be easy to perceive visually is presented as tactile/haptic feedback or information it may be difficult to perceive. |
| Solutions related to accessibility barriers | - Multimodal presentation: Visual or auditory alternatives should be provided for all haptic/tactile information.<br>- Multimodal control: Visual and/or tactile cues should be provided to enable users to quickly re-find all keys and controls during use.<br>- Multimodal control: Mechanisms should be provided that allow all buttons and controls to be located and identified by non-visual means without activating them.<br>- Symbolic/graphical information intended to be presented for tactile/haptic identification should be designed so that it can be clearly identified by the tactile/haptic senses (this may require this information to be much less detailed than would be acceptable for its visual only equivalent). |
| Cultural issues | None identified |
| Benefits of all users: | - It may offer an alternative/complement to visual and acoustic information displayed by the system.<br>- When combined with mid-air and/or 3D stereoscopic displays, this device may provide high-fidelity tactile feedback for interaction with visual objects.<br>- It produces contactless haptic/tactile output. |
| Benefits for older people and people with disabilities | - It offers an alternative to visual and acoustic information, when sight or hearing can not be used while operating the device. |
| Deployment pros | - This technology can produce contactless haptic/tactile output (information can be felt about 20 cm over the surface where the pressure is being generated). |
| Deployment cons | - The produced force is currently sufficient for producing vibratory sensation, but still weak feel constant pressure.<br>- Spatial resolution of the output needs to be improved. |
| Implementation requirements | - To increase the force and spatial resolution of the output. |
| Harmonization | - These displays should adhere to available standards on accessibility of haptic/tactile interactions. |

**Table 6.10.7: Hand-based exoskeletons**

| Characteristic | Definition |
|---|---|
| Name | Hand-based exoskeletons |
| Description | Mechanical devices that are anthropomorphic in nature are 'worn' by an operator and fit closely to the hands, and work in concert with the operator's movements of hands and fingers.<br>The present table is devoted to exoskeletons as force-reflecting technologies that are able to produce haptic/output, e.g. simulation of 3D objects. |
| Mass market deployment | After 2015 |
| Sub category | Finger/hand-based haptic/tactile |
| Related technology | Polymer-based shape displays<br>Body-based exoskeletons |
| User requirements | 06 Be able to invoke and carry out all actions including maintenance and setup<br>14 Understanding the output or displayed material (even after it is perceived accurately)<br>17 Perceive tactile/haptic information |
| Accessibility barriers | - Devices maybe too heavy for some users.<br>- Users may be confused when finding gaps between objects that are intended to be touched. When many haptically enabled objects are in close proximity, getting to a target can become difficult.<br>- Users may have problems to perceive complex haptic objects.<br>- Users may have problems to perceive multiple haptic objects.<br>- Users may have problems to perceive objects requiring a large number of points of contact. |
| Solutions related to accessibility barriers | - Sustained effort minimization: Exoskeletons should be light and portable enough, so that not much force is needed to use them.<br>- Displayed information adjustability: Users should be allowed to control the haptic information to be displayed, as well as its level of detail (e.g. by providing users with support functions to zoom or to navigate through simpler figures).<br>- Low complexity: Tactile/haptic graphics should be sufficiently simple to be recognized without long exploration.<br>- The important elements of a tactile/haptic graphic should be readily perceived by users.<br>- The system should ensure an easily perceivable presentation of multiple tactile/haptic objects. System should allow users to easily identify adjacent tactile/haptic objects.<br>- Object adjustability: The size of a tactile/haptic object should be appropriate and adjustable for the task and to the user's perceptual capabilities. |
| Cultural issues | - Exoskeletons should be portable, silent and fashionable. |
| Benefits of all users: | - Exoskeletons can be used to provide feedback to the hand, as force-reflecting devices technologies that are able to produce haptic/output, e.g. simulation of 3D objects.<br>- It may offer an alternative/complement to visual and acoustic information displayed by the system. |
| Benefits for older people and people with disabilities | - They can be used as assistive technologies.<br>- They can be used to increase human performance and for rehabilitation purposes.<br>- It may offer an alternative/complement to visual and acoustic information displayed by the system. |
| Deployment pros | - They can be used to increase human performance. |
| Deployment cons | - Exoskeleton mechanisms require complex multiple degree-of-freedom (DOF) motorized devices to work in cooperation with the physiology and biomechanics of the involved human body parts (fingers, hands, arms).<br>- Devices are often heavy with limited torque and power, making the wearer's movements difficult to augment.<br>- Devices are often both unnatural in shape and noisy. |
| Implementation requirements | - Exoskeleton mechanisms require complex multiple degree-of-freedom (DOF) motorized devices. |
| Harmonization | - Hand-based exoskeletons should adhere to available standards on accessibility of haptic/tactile interactions. |

**Table 6.10.8: Polymer-based shape displays**

| Characteristic | Definition |
|---|---|
| Name | Polymer-based shape displays |
| Description | Polymer-based displays that may actively or passively change shape via analogue physical inputs. These displays aim to create 3D structures dynamically, with or without visual overlay. By achieving this, these user interfaces aim to incorporate fingers, palm, arm and human manipulation skills into human-computer interaction. |
| Mass market deployment | After 2015 |
| Sub category | Finger/hand-based haptic/tactile |
| Related technology | Dielectric elastomers<br>Hand-based exoskeletons |
| User requirements | 14 Understanding the output or displayed material (even after it is perceived accurately)<br>17 Perceive tactile/haptic information |
| Accessibility barriers | - Users may be confused when finding gaps between objects that are intended to be touched. When many haptically enabled objects are in close proximity, getting to a target can become difficult.<br>- Users may have problems to perceive complex haptic objects.<br>- Users may have problems to perceive multiple haptic objects.<br>- Users may have problems to perceive objects requiring a large number of points of contact. |
| Solutions related to accessibility barriers | - Displayed information adjustability: Users should be allowed to control the haptic information to be displayed, as well as its level of detail (e.g. by providing users with support functions to zoom or to navigate through simpler figures).<br>- Low complexity: Tactile/haptic graphics should be sufficiently simple to be recognized without long exploration.<br>- The important elements of a tactile/haptic graphic should be readily perceived by users of the tactile/haptic display.<br>- The system should ensure an easily perceivable presentation of multiple tactile/haptic objects. System should allow users to easily identify adjacent tactile/haptic objects.<br>- Object adjustability: The size of a tactile/haptic object should be appropriate and adjustable for the task and to the user's perceptual capabilities. |
| Cultural issues | None identified |
| Benefits of all users: | - This technology may support 3D interaction with systems. They may be part of virtual reality systems, e.g. haptic shoes (simulating different grounds, different slopes, etc.).<br>- It may allow simulation of objects' physical properties, such as shape, surface characteristics, etc.<br>- It may offer an alternative/complement to visual and acoustic information displayed by the system. |
| Benefits for older people and people with disabilities | - It offers an alternative to visual and acoustic information, when sight or hearing can not be used while operating the device. |
| Deployment pros | - Polymers are lightweight, inexpensive, fracture tolerant and compliant. They are interesting for integration in haptic devices due to their muscle-like behaviour. |
| Deployment cons | - Complexity of manufacturing technologies supporting 3D dynamic display. |
| Implementation requirements | - Polymers should permit to be deposited in thin films and stacked in a multi-layer configuration, allowing the miniaturization of the actuators. The main challenge today in dielectric polymer technology is to reduce the high voltages required to drive them. |
| Harmonization | - These displays should adhere to available standards on accessibility of haptic/tactile interactions.<br>- Standards on generic ICT accessibility should develop further aspects about haptic/tactile interaction |

**Table 6.10.9: Wearable tactile displays**

| Characteristic | Definition |
|---|---|
| Name | Wearable tactile displays |
| Description | Tactile displays worn by users, normally embedded in clothes and accessories (belts, vests, rings, etc.). |
| Mass market deployment | After 2015 |
| Sub category | Body-based haptic/tactile |
| Related technology | Body-based exoskeletons |
| User requirements | 14 Understand system's output, even if it is perceived by users<br>17 Perceive tactile/haptic information |
| Accessibility barriers | - Tactile information may not be either perceivable or understandable to users. |
| Solutions related to accessibility barriers | - Training need minimization: Wearable tactile displays should minimize the need of training by displaying information that is salient, intuitive and easy to interpret through the sense of touch.<br>- Multimodal presentation: Tactile output should be integrated consistently with visual/acoustic output information from the system.<br>- Barrier-free user education: Tactile patterns should be clearly documented.<br>- The frequency of the tactile signal should be between 150 Hz and 300 Hz for all body areas.<br>- The area of the body to be stimulated should be carefully chosen. A balance should be sought between body areas with higher spatial resolution (e.g. finger tips) and areas with lower spatial resolution but with larger contact area and less obtrusive for other users' daily activities (e.g. back).<br>- Optimum encoding schema should be chosen for tactile information. For this purpose, and generally speaking, locus and duration of the signal should be used rather than frequency and intensity. |
| Cultural issues | - Wearable tactile displays should be light, portable and fashionable. |
| Benefits of all users: | - Tactile signals from wearable displays may be intuitive for individuals.<br>- They can be used in combination with other modalities, as they do not require continuous attention from users.<br>- They can be used for providing spatial orientation and guidance, notifications and alerts, feedback on the progress of system's operations, etc. |
| Benefits for older people and people with disabilities | - Especially useful for people with visual/auditory impairments, e.g. as a complementary/alternative channel to visual/auditory output channels.<br>- Intuitive interaction modality, potentially applicable to people with dementia (e.g. spatial orientation and guidance). |
| Deployment pros | - Electroactive polymers have shown considerable promise as artificial muscles. They may allow integrated joint impedance and motive force controllability, noise-free operation and anthropomorphic device morphologies. |
| Deployment cons | - As these technologies are only effective when worn and people may vary what they wear according to factors such as mood and occasion, it may be difficult to guarantee that the technology is always available when the user requires it.<br>- Users with cognitive impairments may forget to wear the tactile display. |
| Implementation requirements | - Light weight and low power consumption.<br>- Fashionable style.<br>- Adaptability to human body forms. |
| Harmonization | - Systems integrating hand-based exoskeletons should adhere to available standards on accessibility of haptic/tactile interactions. |

**Table 6.10.10: Body-based exoskeletons**

| Characteristic | Definition |
|---|---|
| Name | Body-based exoskeletons |
| Description | Exoskeletons are defined as mechanical devices that are anthropomorphic in nature, are 'worn' by an operator and fit closely to the body, and work in concert with the operator's movements |
| Mass market deployment | After 2015 |
| Sub category | Body-based haptic/tactile |
| Related technology | Wearable tactile displays<br>Hand-based exoskeletons |
| User requirements | 06 Be able to invoke and carry out all actions including maintenance and setup<br>14 Understanding the output or displayed material (even after it is perceived accurately) |
| Accessibility barriers | - Device may be too heavy for users to wear.<br>- System's output may be difficult to understand to users. |
| Solutions related to accessibility barriers | - Sustained effort minimization: Lightweight and highly elastic leg exoskeletons that act in parallel with the human limbs.<br>- The system should allow users to move about and explore the tactile/haptic space, acquiring an accurate understanding of the objects and their arrangement in the space. |
| Cultural issues | - Exoskeletons should be portable, silent and fashionable. |
| Benefits of all users: | - Exoskeletons can be used to provide feedback to the user, as force-reflecting devices technologies that are able to produce haptic/output, e.g. simulation of virtual contexts.<br>- It may offer an alternative/complement to visual and acoustic information displayed by the system. |
| Benefits for older people and people with disabilities | - They can be used as assistive technologies.<br>- It may offer an alternative/complement to visual and acoustic information displayed by the system.<br>- Exoskeletons can be used to increase human performance and for rehabilitation purposes. |
| Deployment pros | - Electroactive polymers have shown considerable promise as artificial muscles. They may allow integrated joint impedance and motive force controllability, noise-free operation and anthropomorphic device morphologies. |
| Deployment cons | - Exoskeleton mechanisms require complex multiple degree-of-freedom (DOF) motorized devices to work in cooperation with the physiology and biomechanics of the involved human body parts.<br>- Devices are often heavy with limited torque and power, making the wearer's movements difficult to augment.<br>- Devices are often both unnatural in shape and noisy.<br>- Limited actuators' durability and lifetime. |
| Implementation requirements | - Neuro-mechanical models that capture the major features of human walking may lead to the design of economical, stable and low-mass exoskeletons for human walking augmentation.<br>- More compact and efficient electronics is needed.<br>- Direct information exchange between the human wearer's nervous system and the wearable device. |
| Harmonization | - Exoskeletons should adhere to available standards on accessibility of haptic/tactile interactions. |

## 6.11 Smell-based output technologies roadmap

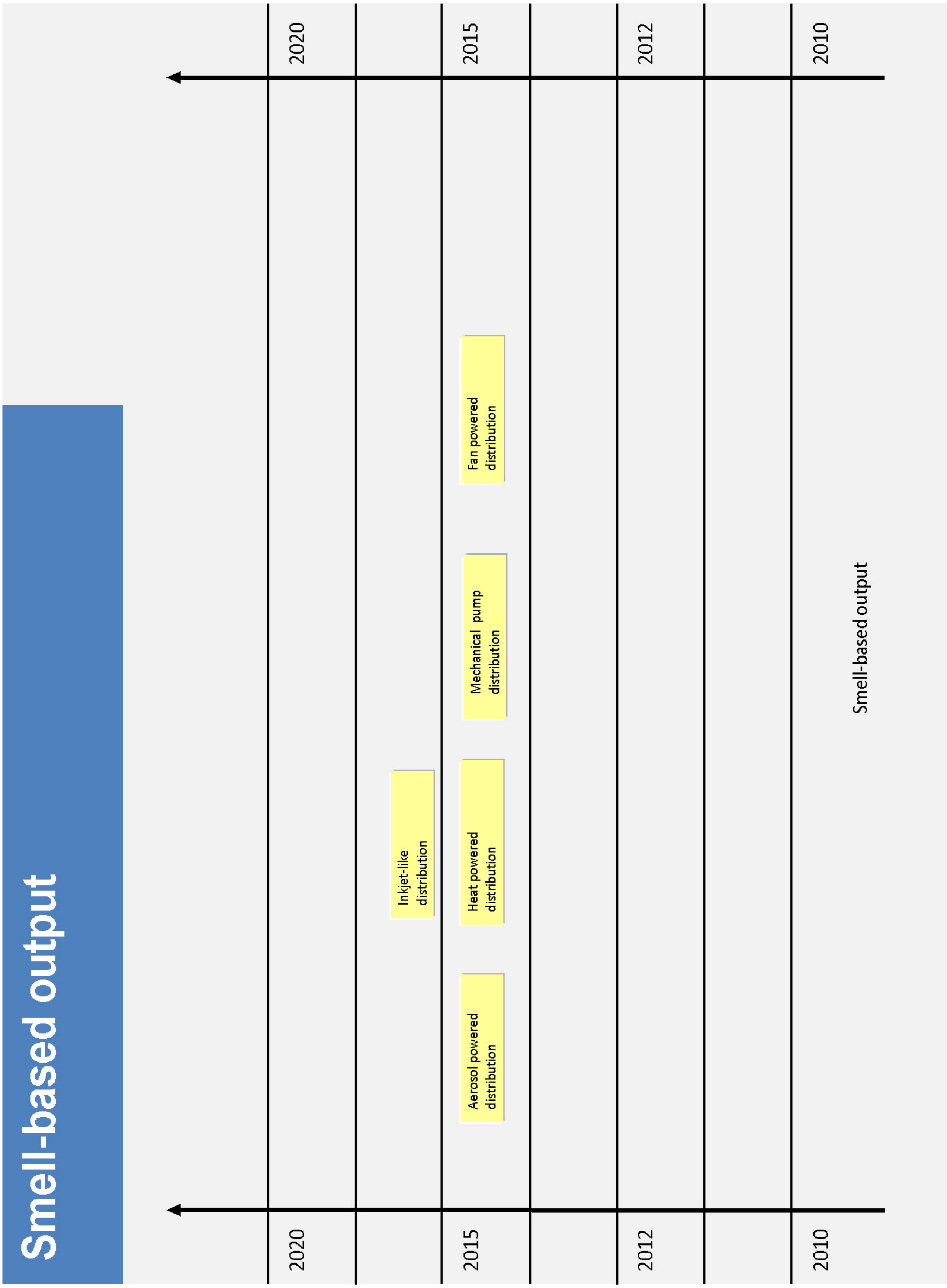


**Figure 6.11.1: Smell-based output technologies roadmap**

Smell and taste are currently not really "used" in user interface development. An exception is the use of smell in the generation of movies provided that movie theatres have the possibility to create smell during presentations.

Smell may be used as a way to enhance and enrich an existing interaction - its use as a stand-alone interaction technology is not advisable for a number of reasons:

- There is no universal or generally accepted interpretation of smell.
- Smell cannot be targeted to one specific user and will be sensed by other people in the environment.
- Smell might by be considered intrusive by users.
- There is a potentially long hysteresis i.e. the time between the generation of smells and their sensing by the user can be long and differ from user to user.
- The human nose adapts very fast to smells, so repetitive smell "events" may not be recognizable by the user.
- People may have differing sensitivity to special smells.
- People may be allergic to certain smells.
- The creation of smell can be energy consuming and is therefore not advisable in portable devices.

Table 6.11.1 gives an alphabetical listing of the technologies covered in this clause.

**Table 6.11.1: Overview of smell-based output technologies**

| User interaction technology | Sub category | Table |
|---|---|---|
| Aerosol powered distribution | Smell-based output | 6.11.2 |
| Fan-powered distribution | Smell-based output | 6.11.5 |
| Heat-powered distribution | Smell-based output | 6.11.6 |
| Inkjet-like distribution | Smell-based output | 6.11.3 |
| Mechanical pump distribution | Smell-based output | 6.11.4 |

**Table 6.11.2: Aerosol powered distribution**

| Characteristic | Definition |
|---|---|
| Name | Aerosol powered distribution |
| Description | Aerosol powered smell distribution devices use aerosols to distribute one or more perfume fluids in the vicinity of a device (similar to standard perfume dispensers). |
| Mass market deployment | After 2015 |
| Sub category | Smell-based output |
| Related technology | Taste-based output technologies |
| User requirements | 04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>14 Understand the output or displayed material |
| Accessibility barriers | - Inability to perceive smell. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Cultural issues | - Interpretation of taste and/or smell may be culturally different.<br>- Users may interpret smell output as an intrusion of their privacy. |
| Benefit for all users | - Allows for additional means to transmit status information and sensations. |
| Benefits for older people and people with disabilities | - Allows for additional means to transmit status information for people with multiple sensory disabilities. |
| Deployment pros | - Additional sensual channel usable. |
| Deployment cons | - No clear and socially accepted interpretation of taste and smell available.<br>- Potentially long latency between activation and sensory reaction.<br>- Smell sensibility changes over user lifetime.<br>- Potentially high energy needs.<br>- Aging of materials (perfumes).<br>- Risk of allergic reactions. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.11.3: Inkjet-like distribution**

| Characteristic | Definition |
|---|---|
| Name | Inkjet-like distribution |
| Description | Inkjet-like distribution of perfumes allows for very exact dosage of a large number of perfume fluids to create complex smells. Usually the distribution needs to be supported by a device which enables air movement (fan, air conditioning system). |
| Mass market deployment | After 2015 |
| Sub category | Smell-based output |
| Related technology | Taste-based output technologies |
| User requirements | 04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>14 Understand the output or displayed material |
| Accessibility barriers | - Inability to perceive smell. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Cultural issues | - Interpretation of taste and/or smell may be culturally different.<br>- Users may interpret smell output as an intrusion of their privacy. |
| Benefit for all users | - Allows for additional means to transmit status information and sensations. |
| Benefits for older people and people with disabilities | - Allows for additional means to transmit status information for people with multiple sensory disabilities. |
| Deployment pros | - Additional sensual channel usable. |
| Deployment cons | - No clear and socially accepted interpretation of taste and smell available.<br>- Potentially long latency between activation and sensory reaction.<br>- Smell sensibility changes over user lifetime.<br>- Potentially high energy needs.<br>- Aging of materials (perfumes).<br>- Risk of allergic reactions. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Implementation requirements | None identified |

**Table 6.11.4: Mechanical pump distribution**

| Characteristic | Definition |
|---|---|
| Name | Mechanical pump distribution |
| Description | Mechanical pump distribution replaces chemical dispensing solutions through the use of mechanically created air pressure. |
| Mass market deployment | After 2015 |
| Sub category | Smell-based output |
| Related technology | Taste-based output technologies |
| User requirements | 04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>14 Understand the output or displayed material |
| Accessibility barriers | - Inability to perceive smell. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Cultural issues | - Interpretation of taste and/or smell may be culturally different.<br>- Users may interpret smell output as an intrusion of their privacy. |
| Benefit for all users | - Allows for additional means to transmit status information and sensations. |
| Benefits for older people and people with disabilities | - Allows for additional means to transmit status information for people with multiple sensory disabilities. |
| Deployment pros | - Additional sensual channel usable. |
| Deployment cons | - No clear and socially accepted interpretation of taste and smell available.<br>- Potentially long latency between activation and sensory reaction.<br>- Smell sensibility changes over user lifetime.<br>- Potentially high energy needs.<br>- Aging of materials (perfumes).<br>- Risk of allergic reactions. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Implementation requirements | None identified |

**Table 6.11.5: Fan-powered distribution**

| Characteristic | Definition |
|---|---|
| Name | Fan powered distribution |
| Description | Fan powered distribution is the distribution through a continuous airflow over one or more perfume surfaces to distribute smell in a larger area. |
| Mass market deployment | After 2015 |
| Sub category | Smell-based output |
| Related technology | Taste-based output technologies |
| User requirements | 04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>14 Understand the output or displayed material |
| Accessibility barriers | - Inability to perceive smell. |
| Solutions related to accessibility barriers | Ensure availability of alternative modalities for information presentation. |
| Cultural issues | - Interpretation of taste and/or smell may be culturally different.<br>- Users may interpret smell output as an intrusion of their privacy. |
| Benefit for all users | - Allows for additional means to transmit status information and sensations. |
| Benefits for older people and people with disabilities | - Allows for additional means to transmit status information for people with multiple sensory disabilities. |
| Deployment pros | - Additional sensual channel usable. |
| Deployment cons | - No clear and socially accepted interpretation of taste and smell available.<br>- Potentially long latency between activation and sensory reaction.<br>- Smell sensibility changes over user lifetime.<br>- Potentially high energy needs.<br>- Aging of materials (perfumes).<br>- Risk of allergic reactions. |
| Solutions related to accessibility barriers | Ensure availability of alternative modalities for information presentation. |
| Implementation requirements | None identified |

**Table 6.11.6: Heat-powered distribution**

| Characteristic | Definition |
|---|---|
| Name | Heat-powered distribution |
| Description | Heat powered distribution uses heat to evaporate the smell of wax-based perfumes. The heat can also be used to distribute the smell in a larger environment. This technology has a very large latency compared to other distribution methods. |
| Mass market deployment | After 2015 |
| Sub category | Smell-based output |
| Related technology | Taste-based output technologies |
| User requirements | 04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>14 Understand the output or displayed material |
| Accessibility barriers | - Inability to perceive smell. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Cultural issues | - Interpretation of taste and/or smell may be culturally different.<br>- Users may interpret smell output as an intrusion of their privacy. |
| Benefit for all users | - Allows for additional means to transmit status information and sensations. |
| Benefits for older people and people with disabilities | - Allows for additional means to transmit status information for people with multiple sensory disabilities. |
| Deployment pros | - Additional sensual channel usable. |
| Deployment cons | - No clear and socially accepted interpretation of taste and smell available.<br>- Potentially long latency between activation and sensory reaction.<br>- Smell sensibility changes over user lifetime.<br>- Potentially high energy needs.<br>- Aging of materials (perfumes).<br>- Risk of allergic reactions. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Implementation requirements | None identified |

## 6.12 Taste-based output technologies roadmap

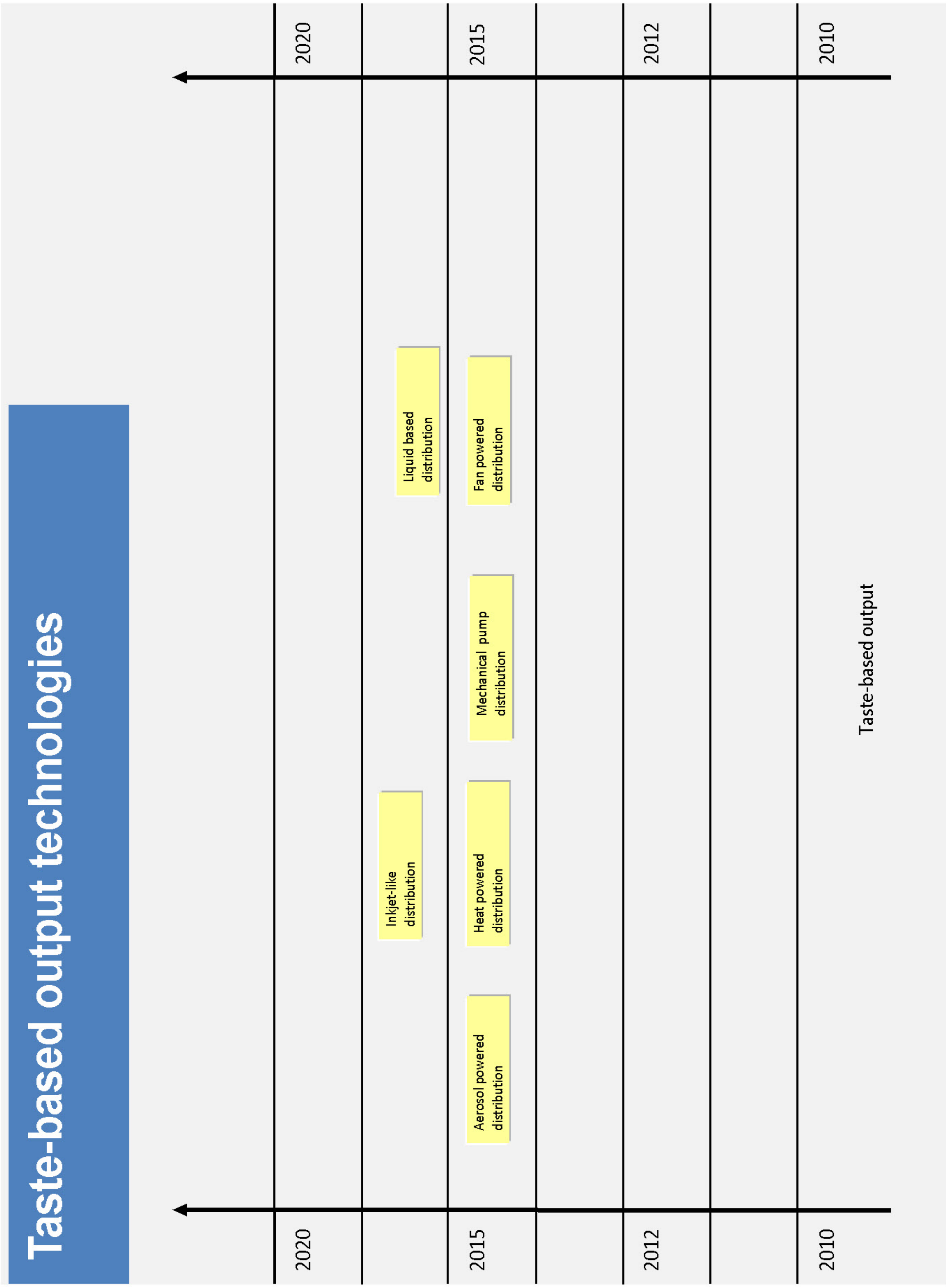


**Figure 6.12.1: Taste-based output technologies roadmap**

Smell and taste are currently not really "used" in user interface development. The creation of taste events is very similar to that of smells, using similar carriers but different perfumes which can be sensed by the human.

Taste may be used as a way to enhance and enrich an existing interaction - its use as a stand-alone interaction technology is not advisable for a number of reasons:

- Taste cannot be targeted to one specific user when transmitted through the air and will be sensed by other people in the environment. Alternative delivery methods using e.g. means to put into the user's mouth will probably not be accepted by users.
- Taste may by be considered intrusive by users.
- There is a potentially long hysteresis i.e. the time between the generation of tastes and their sensing by the user can be long and differ from user to user.
- People may have differing sensitivity to special tastes. This sensitivity my change when people get older.
- People may be allergic to certain tastes.
- The creation of smell can be energy consuming and is therefore not advisable in portable devices.

Table 6.12.1 gives an alphabetical listing of the technologies covered in this clause.

**Table 6.12.1: Overview of taste-based output technologies**

| User interaction technology | Sub category | Table |
|---|---|---|
| Aerosol powered distribution | Taste-based output | 6.12.2 |
| Fan powered distribution | Taste-based output | 6.12.6 |
| Heat powered distribution | Taste-based output | 6.12.3 |
| Inkjet-like distribution | Taste-based output | 6.12.4 |
| Liquid-based distribution | Taste-based output | 6.12.7 |
| Mechanical pump distribution | Taste-based output | 6.12.5 |

**Table 6.12.2: Aerosol powered distribution**

| Characteristic | Definition |
|---|---|
| Name | Aerosol powered distribution |
| Description | Aerosol powered smell distribution devices use aerosols to distribute one or more perfume fluids in the vicinity of a device (similar to standard perfume dispensers). The dispensed fluid contains chemicals which create a sour, bitter, salty or sweet sensation when in contact with taste buds on the human tongue. |
| Mass market deployment | After 2015 |
| Sub category | Taste-based output |
| Related technology | Smell-based output technologies |
| User requirements | 04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>14 Understand the output or displayed material |
| Accessibility barriers | - People may be insensitive to tastes and not recognize tastes. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Cultural issues | - Interpretation of taste and/or smell may be culturally different.<br>- Users may interpret taste output as an intrusion of their privacy. |
| Benefit for all users | - Allows for additional means to transmit status information and sensations. |
| Benefits for older people and people with disabilities | - Allows for additional means to transmit status information for people with multiple sensory disabilities. |
| Deployment pros | - Additional sensual channel usable. |
| Deployment cons | - No clear and socially accepted interpretation of taste and smell available.<br>- Potentially long latency between activation and sensory reaction.<br>- Taste sensibility changes over user lifetime.<br>- Potentially high energy needs.<br>- Aging of materials (perfumes).<br>- Risk of allergic reactions. |
| Implementation requirements | - Requires strong power supply. |
| Harmonization | None identified |

**Table 6.12.3: Heat powered distribution**

| Characteristic | Definition |
|---|---|
| Name | Heat powered distribution |
| Description | Heat powered distribution uses heat to evaporate the contents of wax-based perfumes. The heat can also be used to distribute the contents in a larger environment. This technology has a very large latency compared to other distribution methods. The evaporated material contains chemicals which create a sour, bitter, salty or sweet sensation when in contact with taste buds on the human tongue. |
| Mass market deployment | After 2015 |
| Sub category | Taste-based output |
| Related technology | Smell-based output technologies |
| User requirements | 04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>14 Understand the output or displayed material |
| Accessibility barriers | - People may be insensitive to tastes and not recognize tastes. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Cultural issues | - Interpretation of taste and/or smell may be culturally different.<br>- Users may interpret taste output as an intrusion of their privacy. |
| Benefit for all users | - Allows for additional means to transmit status information and sensations. |
| Benefits for older people and people with disabilities | - Allows for additional means to transmit status information for people with multiple sensory disabilities. |
| Deployment pros | - Additional sensual channel usable. |
| Deployment cons | - No clear and socially accepted interpretation of taste and smell available.<br>- Potentially long latency between activation and sensory reaction.<br>- Taste sensibility changes over user lifetime.<br>- Potentially high energy needs.<br>- Aging of materials (perfumes).<br>- Risk of allergic reactions. |
| Implementation requirements | - Requires strong power supply. |
| Harmonization | None identified |

**Table 6.12.4: Inkjet-like distribution**

| Characteristic | Definition |
|---|---|
| Name | Inkjet-like distribution |
| Description | Inkjet-like distribution of perfumes allows for very exact dosage of a large number of perfume fluids to create complex smells. Usually the distribution needs to be supported by a device which enables air movement (fan, air conditioning system). The dispensed fluid contains chemicals which create a sour, bitter, salty or sweet sensation when in contact with taste buds on the human tongue. |
| Mass market deployment | After 2015 |
| Sub category | Taste-based output |
| Related technology | Smell-based output technologies |
| User requirements | 04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>14 Understand the output or displayed material |
| Accessibility barriers | - People may be insensitive to tastes and not recognize tastes. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Cultural issues | - Interpretation of taste and/or smell may be culturally different.<br>- Users may interpret taste output as an intrusion of their privacy. |
| Benefit for all users | - Allows for additional means to transmit status information and sensations. |
| Benefits for older people and people with disabilities | - Allows for additional means to transmit status information for people with multiple sensory disabilities. |
| Deployment pros | - Additional sensual channel usable. |
| Deployment cons | - No clear and socially accepted interpretation of taste and smell available.<br>- Potentially long latency between activation and sensory reaction.<br>- Taste sensibility changes over user lifetime.<br>- Potentially high energy needs.<br>- Aging of materials (perfumes).<br>- Risk of allergic reactions. |
| Implementation requirements | - Requires strong power supply. |
| Harmonization | None identified |

**Table 6.12.5: Mechanical pump distribution**

| Characteristic | Definition |
|---|---|
| Name | Mechanical pump distribution |
| Description | Mechanical pump distribution replaces chemical dispensing solutions through the use of mechanically created air pressure. |
| Mass market deployment | After 2015 |
| Sub category | Taste-based output |
| Related technology | Smell-based output technologies |
| User requirements | 04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>14 Understand the output or displayed material |
| Accessibility barriers | - People may be insensitive to tastes and not recognize tastes. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Cultural issues | - Interpretation of taste and/or smell may be culturally different.<br>- Users may interpret taste output as an intrusion of their privacy. |
| Benefit for all users | - Allows for additional means to transmit status information and sensations. |
| Benefits for older people and people with disabilities | - Allows for additional means to transmit status information for people with multiple sensory disabilities. |
| Deployment pros | - Additional sensual channel usable. |
| Deployment cons | - No clear and socially accepted interpretation of taste and smell available.<br>- Potentially long latency between activation and sensory reaction.<br>- Taste sensibility changes over user lifetime.<br>- Potentially high energy needs.<br>- Aging of materials (perfumes).<br>- Risk of allergic reactions. |
| Implementation requirements | - Requires strong power supply. |
| Harmonization | None identified |

**Table 6.12.6: Fan powered distribution**

| Characteristic | Definition |
|---|---|
| Name | Fan powered distribution |
| Description | Fan powered distribution is the distribution through a continuous airflow over one or more perfume surfaces to distribute taste in a larger area. |
| Mass market deployment | After 2015 |
| Sub category | Taste-based output |
| Related technology | Smell-based output technologies |
| User requirements | 04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>14 Understand the output or displayed material |
| Accessibility barriers | - People may be insensitive to tastes and not recognize tastes. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Cultural issues | - Interpretation of taste and/or smell may be culturally different.<br>- Users may interpret taste output as an intrusion of their privacy. |
| Benefit for all users | - Allows for additional means to transmit status information and sensations. |
| Benefits for older people and people with disabilities | - Allows for additional means to transmit status information for people with multiple sensory disabilities. |
| Deployment pros | - Additional sensual channel usable. |
| Deployment cons | - No clear and socially accepted interpretation of taste and smell available.<br>- Potentially long latency between activation and sensory reaction.<br>- Taste sensibility changes over user lifetime.<br>- Potentially high energy needs.<br>- Aging of materials (perfumes).<br>- Risk of allergic reactions. |
| Implementation requirements | - Requires strong power supply. |
| Harmonization | None identified |

**Table 6.12.7: Liquid-based distribution**

| Characteristic | Definition |
|---|---|
| Name | Liquid-based distribution |
| Description | Liquid-based distribution of taste components uses a thin tube to transport small amounts of liquids directly to the taste buds on the human tongue. These liquids create a sour, salty, bitter or sweet sensation on the tongue. |
| Mass market deployment | After 2015 |
| Sub category | Taste-based output |
| Related technology | Smell-based output technologies |
| User requirements | 04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>14 Understand the output or displayed material |
| Accessibility barriers | - People may be insensitive to tastes and not recognize tastes. |
| Solutions related to accessibility barriers | - Ensure availability of alternative modalities for information presentation. |
| Cultural issues | - Interpretation of taste and/or smell may be culturally different.<br>- Users may interpret taste output as an intrusion of their privacy.<br>- Use of a tube may cause hygienic objections. |
| Benefit for all users | - Allows for additional means to transmit status information and sensations. |
| Benefits for older people and people with disabilities | - Allows for additional means to transmit status information for people with multiple sensory disabilities. |
| Deployment pros | - Additional sensual channel usable. |
| Deployment cons | - No clear and socially accepted interpretation of taste and smell available.<br>- Taste sensibility changes over user lifetime.<br>- Potentially high energy needs.<br>- Risk of allergic reactions. |
| Implementation requirements | - Requires strong power supply. |
| Harmonization | None identified |

# 6.13 Visual output technologies roadmap

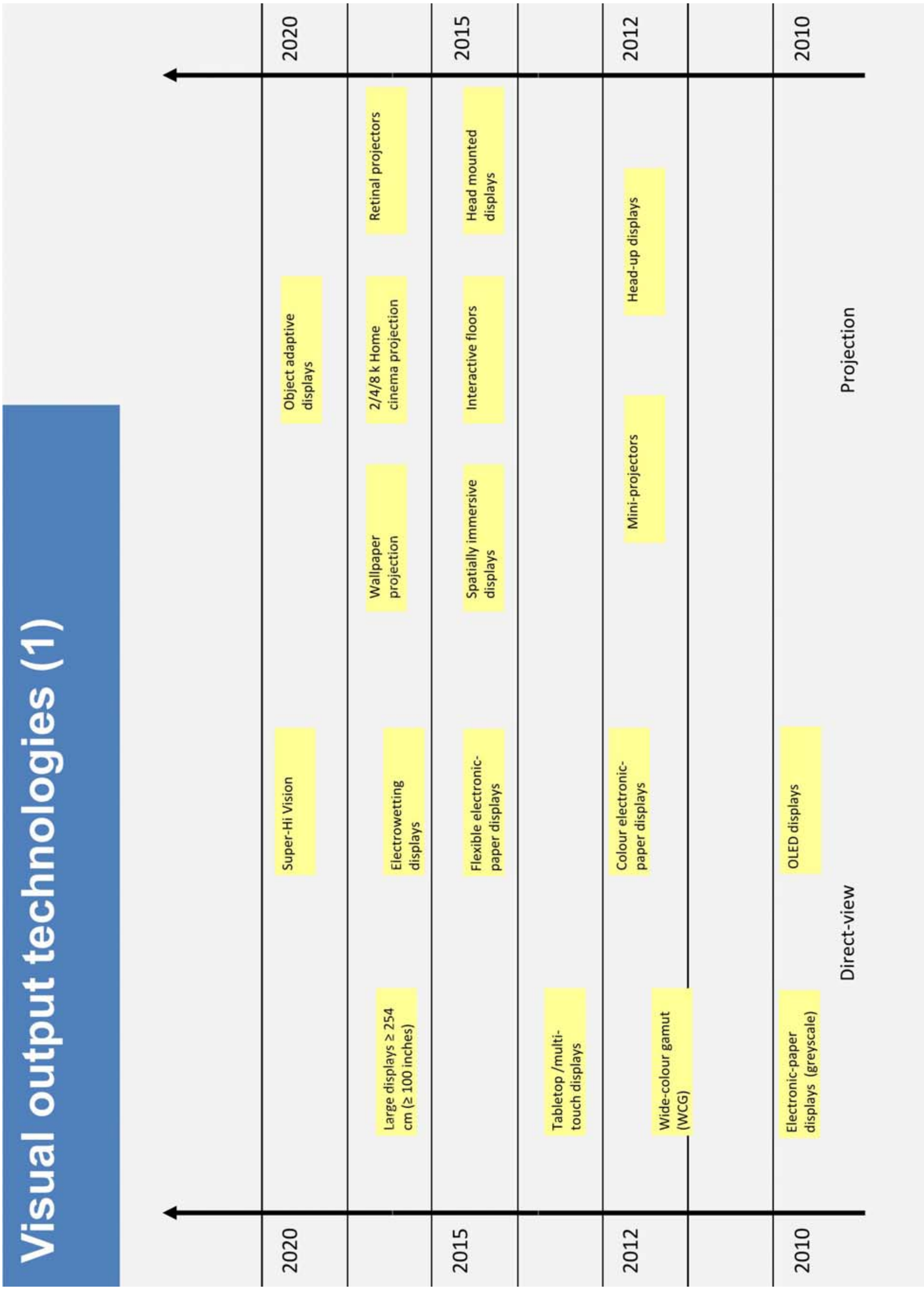


**Figure 6.13.1: Visual output technologies roadmap (1)**

The visual output technology roadmaps are divided into five different sub-categories shown in three figures: "Direct-view" and "Projection" based technologies are given in figure 6.12.1, "Handheld/mobile' and "Visual AR" technologies in figure 6.12.2 and finally, "2D/3D switchable" displays in figure 6.12.3.

Research and development for visual output technologies is vibrant and diverse, with competing and innovative technologies being developed at a fast pace. These technologies will enable displays to be improved and used in eServices in novel ways.

The key developments in the area of Direct-view, visual output technologies are:

- attempts to overcome some of the known limitations associated with traditional, backlit Liquid Crystal Displays (LCDs);
- improved viewing experience, e.g. through increased display resolution, field-of-viewing (FOV) angle, colour space or size of the display;
- displays with substantially reduced power consumption and less rigid form factor both of which are better at supporting a mobile, battery-driven operation.

Direct-view visual output technologies provide the ability to use a wider and more enhanced variety (and alternatives) of different visual outputs as the flexible displays become more common and reductions in power consumption might lead to more alternatives types of mobile display. However, the innovative visual output technologies may also cause problems for users and especially users with (visual-) impairments:

- Visual content may not be accessible at all or only accessible to a certain extent to people with visual impairments.
- Novel visual output technologies might not provide the content or control other than by the visual channel.
- Visually impaired users may find it difficult to identify controls (e.g. location of on/off controls) and indications (e.g. indicating status of device, transmitting or idle).

Solutions for these and other accessibility barriers identified for individual or several visual output technologies are listed in the tables 6.13.1 to 6.13.18 and include:

- multimodal controls and indications offering access to a device or eService by means of more than one sensory modality;
- provision of multimodal presentation of visual content as an alternative option;
- ensuring connectivity to assistive devices;
- reduced complexity modes ensuring that important and/or critical functionality is easily accessible by all users including those with severe impairments.

Projection of images on surfaces represents one of the classical approaches to implement the visual output of a system. Emerging projection technologies can be applied to a number of future eServices. For instance, arrays of projectors designed to run as a single logical device represent an alternative to other technologies supporting virtual environments.

Benefits of using projectors include, but are not limited to:

- adaptability to existing spaces and objects where visual information is to be projected;
- reduced infrastructure changes and maintenance;
- potentially unlimited field of view;
- ability to share visual content between multiple people on an ad-hoc basis.

Projection technologies addressed in the present document cover projection on large surfaces, on curved surfaces, on head-mounted devices, on user's retina, etc.

Main accessibility barriers for using these technologies have to do with:

- degradation of visual output caused either by the geometric relationship between the projector and display surface, the material the surface is made of, changing light conditions, shadows caused by objects or persons, etc;
- problems in perceiving foreground information on changing backgrounds;
- users being unaware of context obstacles or dangerous situations that are either not displayed by the system or are not perceived by the users;
- users being distracted from other important (even vital) tasks such as driving.

Solutions to these barriers include:

- consistent integration of visual output with other interaction modalities (e.g. audio, haptic/tactile);
- use of intelligent arrays of projectors including sensing of what is actually being projected;
- allowing users to configure display characteristics;
- using robust rendering algorithms to ensure that foreground information is perceivable on changing backgrounds;
- alerting users of immersive systems to potential risks in the real environment;
- providing clear instructions on when this technology can be used and when not.

People considering the use of the type of visual output technologies covered in this clause in ICT devices and services can find additional useful insights and information in the following sources: [Liu & Wen, 2004] (Head-up displays); [Sun et al, 2008], [Jaynes, Webb & Steele, 2004] (multi-projector based systems). Some of the references used in the Visual AR sub-category are also applicable to the Projection sub-category.

Table 6.13.1 gives an alphabetical listing of the technologies covered in this clause.

**Table 6.13.1: Overview of visual output technologies (1)**

| User interaction technology | Sub category | Table |
|---|---|---|
| 2/4/8 k Home cinema projection | Projection | 6.13.17 |
| Colour electronic-paper displays | Direct-view | 6.13.5 |
| Electronic-paper displays (greyscale) | Direct-view | 6.13.2 |
| Electrowetting displays | Direct-view | 6.13.8 |
| Flexible electronic-paper displays | Direct-view | 6.13.7 |
| Head mounted displays | Projection | 6.13.15 |
| Head-up displays (HUD) | Projection | 6.13.12 |
| Interactive floors | Projection | 6.13.14 |
| Large displays ≥ 254 cm (≥ 100 inches) | Direct-view | 6.13.9 |
| Mini-projectors | Projection | 6.13.11 |
| Object adaptive projection | Projection | 6.13.19 |
| OLED displays | Direct-view | 6.13.3 |
| Retinal projectors | Projection | 6.13.18 |
| Spatially immersive displays | Projection | 6.13.13 |
| Super-Hi Vision | Direct-view | 6.13.10 |
| Tabletops/multi-touch displays | Direct-view | 6.13.6 |
| Wallpaper projection | Projection | 6.13.16 |
| Wide-colour gamut (WCG) | Direct-view | 6.13.4 |

**Table 6.13.2: Electronic paper displays (greyscale)**

| Characteristic | Definition |
|---|---|
| Name | Electronic paper displays (greyscale) |
| Description | Electronic paper displays (greyscale) allow low-power operation as the display is not backlight-illuminated (reflective light is used) and does not need to be "refreshed"; sufficient contrast and resolution (readable in sunlight; resolution matching or exceeding printed newspapers) have made it a display technology found today in devices such as e-book readers. |
| Mass market deployment | By 2012 |
| Sub category | Direct-view |
| Related technology | Colour electronic-paper displays<br>Flexible electronic-paper displays<br>Electrowetting displays<br>OLED displays |
| User requirements | 01 Perceive visual information<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- Display needs to provide for adequate operations to adapt the displayed content to personal preferences.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | - Reading (texts) and changing displayed content (switching 'pages') should accommodate culturally different directions of reading. |
| Benefit for all users | - Low-power, good contrast, long operating time; thin-display, comfortable reading of text-/greyscale information with low refresh-rate needs. |
| Benefits for older people and people with disabilities | - Provision of (analogue) media content in a form that is accessible to people who cannot handle (analogue) media content (e.g. holding a book or turning a page manually). |
| Deployment pros | - Low weight as compared to printed media content such as books. |
| Deployment cons | - Some electronic paper technologies are unable to show content requiring high-refresh rates like videos/animations, interactive elements.<br>- Vividness of coloured content is missing.<br>- Proprietary formats of media delivery due to competing, but incompatible business models used in the market.<br>- Ability to transform materials or access them as audio book-formats or digital talking books needed. |
| Implementation requirements | - The choice of electronic paper technology used for each specific application should take account of the need to display rapidly moving content and the ability of the chosen technology to support this. |
| Harmonization | - Text/content/media exchange formats, transformation of visual into auditory content and connecting technologies (connectors/networking). |

**Table 6.13.3: OLED displays**

| Characteristic | Definition |
|---|---|
| Name | OLED (Organic light emitting diode) displays |
| Description | A display that is build up from a film of organic compounds emitting light when electric current is flowing through it. The display is based upon the light-emitting diode (LED) technique working on the principle of emissive electroluminance, giving this kind of displays very different characteristics from LCD displays for example. |
| Mass market deployment | By 2012 |
| Sub category | Direct-view |
| Related technology | Colour electronic paper displays<br>Flexible electronic paper displays |
| User requirements | 01 Perceive visual information |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- Display needs to provide for adequate operations to adapt the displayed content to personal preferences.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | None identified |
| Benefit for all users | - OLED displays can be built with a very slim (and lighter) form factor (making them very suitable for small mobile systems).<br>- They may provide a greater artificial contrast ratio and may display the image at a larger viewing angle as compared to a current LCD display.<br>- As OLEDs can be put onto flexible base material OLEDs are one way to achieve flexible e-paper displays. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - New display usages if a flexible substrate is used as carrier of the light emitting substances.<br>- Smaller and lighter form factor achievable as compared to LCD displays.<br>- OLED display technology could become cheaper to manufacture as recent advance in Active-Matrix addressing of OLED displays (so called AMOLEDs) allow for greater OLED display sizes to be manufactured. |
| Deployment cons | - OLED displays have been struggling with a limited life expectancy of the organic materials used.<br>- Outdoor (sunshine) lightening conditions can be problematic as OLED displays do not use reflective lighting.<br>- In display conditions where content is shown on a white background (e.g. texts, web-pages), current OLED displays use more power than comparable LCD displays. |
| Implementation requirements | - Life expectancy of organic materials needs to be improved, displays (especially larger ones) need to compatible in price. |
| Harmonization | None identified |

**Table 6.13.4: Wide-colour gamut (WCG)**

| Characteristic | Definition |
|---|---|
| Name | Wide-colour gamut (WCG) |
| Description | Display that allows an increased colour space to be shown; the extended colour display is experienced as a more intensive display, especially for photorealistic images. |
| Mass market deployment | By 2012 |
| Sub category | Direct-view |
| Related technology | None identified |
| User requirements | 01 Perceive visual information |
| Accessibility barriers | - Extended colour space might not be perceivable by all users. |
| Solutions related to accessibility barriers | - Object adjustability: allow the size of displayed objects to be adjustable.<br>- Displayed information adjustability: Allow for flexible adjustment of the displayed information.<br>- Information should not be encoded only through colour. |
| Cultural issues | None identified |
| Benefit for all users | - Improved viewing experience. |
| Benefits for older people and people with disabilities | - Potentially the ability to enhance visual display parameters as compared to standard-colour space screens. |
| Deployment pros | - Multiple display preference settings for different content types and accessibility needs possible. |
| Deployment cons | - Might require manual (colour) calibration. |
| Implementation requirements | None identified |
| Harmonization | - Standards for (automatic) (colour-space) display profiles and colour conversion, e.g. for printing, if not already covered by existing ones. |

**Table 6.13.5: Colour electronic paper displays**

| Characteristic | Definition |
|---|---|
| Name | Colour electronic paper displays |
| Description | This display type is a closely related "variant" of (greyscale/flexible) e-paper/ink display technologies; the main characteristic is that the displays will be able to display colour, and probably moving images (video and animations), i.e. it will work with a display refresh frequency suitable for video/animations. |
| Mass market deployment | By 2012 |
| Sub category | Direct-view |
| Related technology | Electronic paper displays (greyscale)<br>Flexible electronic paper displays<br>Electrowetting displays |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- Display needs to provide for adequate operations to adapt the displayed content to personal preferences.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | None identified |
| Benefit for all users | - Similar to the benefits of the (greyscale) e-paper/ink displays.<br>- Low-power and long-operation times.<br>- Comfortable reading of text and perception of other content types.<br>- Displays are expected to provide significantly brighter images than current reflective LCD displays. |
| Benefits for older people and people with disabilities | - Content might be provided in a form superior to its analogue counterpart due to the physical attributes (i.e. display and device lighter than a heavy book).<br>- Ability to set individual (display) preferences. |
| Deployment pros | - Ability to even display colour images and, most importantly, video.<br>- Low weight as compared to printed media content e.g. books. |
| Deployment cons | - Some electronic paper technologies may be unable to show content requiring high-refresh rates like videos/animations, interactive elements.<br>- Display technology needs to become stable enough for long-term usage.<br>- Colour and resolution need to be fit for purpose (depending upon appliance and purpose e.g. video and watching sports transmissions). |
| Implementation requirements | - The choice of electronic paper technology used for each specific application should take account of the need to display rapidly moving content and the ability of the chosen technology to support this.<br>- Depending upon context this display type will probably be used in settings where multimedia is used as content to be displayed i.e. other components (e.g. acoustic output technologies) need to considered.<br>- Accessibility for the different media types need to be designed for accordingly. |
| Harmonization | - Text and content exchange formats and connecting technologies (connectors/networking). |

**Table 6.13.6: Tabletops/multi-touch displays**

| Characteristic | Definition |
|---|---|
| Name | Tabletop/multi-touch displays |
| Description | Tabletops allow the change from vertical to horizontal positioning. This switch of the display surface makes it possible to allow for other means of manipulating graphical representations on the screen e.g. allowing input and manipulation through touch (gestures). Use of this display may lead to changes of furniture such as tables and may involve changing the material, form factor and function. |
| Mass market deployment | By 2015 |
| Sub category | Direct-view |
| Related technology | Tactile Input/Multi-touch |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out all actions including maintenance and setup<br>07 Be able to complete actions and tasks within the time allowed<br>08 Avoid unintentional activation of controls<br>09 Be able to recover from errors<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any access features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Display surfaces should be reachable by all users, including by people in wheelchairs.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: support flexible displayed information adjustment.<br>- User limitation compensation: the placement and reachability of the display should take into account the needs of all users, including wheelchair users and, where appropriate, young children.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | - Hygienic requirements. |
| Benefit for all users | - Touch sensitive displays with "multi-touch recognition" embedded into flat, horizontal surfaces.<br>- Simultaneous usage by multiple users may be possible.<br>- Ability to fuse with other "smart objects" in ambient intelligence/home automation situations. |
| Benefits for older people and people with disabilities | - Touch display potentially operative in a sitting/lying position.<br>- Multi-touch recognition possible to give better control. |
| Deployment pros | - May be fitted in existing flat surfaces such as tables in the home. |
| Deployment cons | - Weight of displays may prevent flexible movement of display-furniture.<br>- Reflection from (above) lightning may pose a problem for visibility.<br>- Tables or similar flat surfaces may not have power supply nearby. |
| Implementation requirements | None Identified |
| Harmonization | - Possible interconnection to interactive objects to work in combination with this display (e.g. through near-field networking/RFID or similar) |

### Table 6.13.7: Flexible electronic-paper displays

| Characteristic | Definition |
|---|---|
| Name | Flexible electronic-paper displays |
| Description | This display technology can be understood as a "variant" of e-paper/ink display technologies; here, the main characteristics is that the displays will be *flexible* enough that it can be bend, perhaps even be truly foldable one day (unclear if this goal can be reached). The physical flexibility of this display technology will make new usages possible where rigid display technologies are unsuitable. |
| Mass market deployment | After 2015 |
| Sub category | Direct-view |
| Related technology | Electronic-paper displays(greyscale)<br>Colour electronic-paper displays<br>Flexible electronic-paper displays<br>Electrowetting displays<br>OLED displays |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>12 Be able to efficiently operate product<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Flexible displays may come in a form that makes "un/packing" the actual display necessary before (and after) usage; this operation also needs to be accessible.<br>- Displayed content might not be accessible for people with visual impairments.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - User limitation compensation: for un/packing the display components.<br>- Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: support flexible displayed information adjustment.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | None identified |
| Benefit for all users | - Displays without rigid form factor.<br>- Increased mobility due to the flexible material and thinness of the display.<br>- Low-power need and long operating time.<br>- Comfortable reading of text- information with low refresh-rate needs. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - Possibility to provide for visual displays in locations/for purposes previously banned due to the non-flexible surface of displays.<br>- New form-factors, especially for mobile ICT systems, as the display/screen can be stored in new forms while they are not used. |
| Deployment cons | - Some electronic paper technologies may be unable to show content requiring high-refresh rates like videos/animations, interactive elements.<br>- Display technology needs to become robust enough for acceptable bending or flexing cycles. |
| Implementation requirements | - The choice of electronic paper technology used for each specific application should take account of the need to display rapidly moving content and the ability of the chosen technology to support this. |
| Harmonization | - Connecting technologies (connectors/networking). |

**Table 6.13.8: Electrowetting displays**

| Characteristic | Definition |
|---|---|
| Name | Electrowetting displays |
| Description | Electrowetting is currently an "umbrella term" for different display technologies to manipulate fluids (instead of liquid crystals in a LCD display). These fluids are used to cover the (reflective/transmissive) light source used. Different systems under development attempt to provide for higher brightness (due to larger transmission of light) than current LCD-displays. Other attempted/demonstrated benefits can be an increased viewing angle (again compared to current LCDs), the ability to display video (by usage of "field sequential colour" techniques for example) or a bi-stable, binary display that is able to hold the displayed image even without power over a long period of time (month to years). |
| Mass market deployment | After 2015 |
| Sub category | Direct-view |
| Related technology | Colour electronic-paper displays<br>Flexible electronic-paper displays |
| User requirements | 01 Perceive visual information<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | None identified |
| Benefit for all users | - Similar to the benefits of the (greyscale) e-paper/ink displays.<br>- Low-power and long-operation times.<br>- Comfortable reading of text and perception of other content types.<br>- Displays are expected to provide significant brighter images than current reflective LCD displays. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - Possibly able to display colour images and video.<br>- Bi-stable binary display technologies are predestined in usages where displays still need to be readable in case of power-failures or dependent upon self-sufficient (outdoor/solar-panel) energy supply forms. |
| Deployment cons | - Display technology needs to become stable enough for long-term usage.<br>- Colour and resolution need to be fit for purpose (depending upon appliance or service). |
| Implementation requirements | None identified |
| Harmonization | None identified |

**Table 6.13.9: Large displays ≥ 254 cm (≥ 100 inches)**

| Characteristic | Definition |
|---|---|
| Name | Large displays ≥ 254 cm(≥ 100 inches) |
| Description | Very large monitors with a diagonal display size of ≥ 254 cm (≥ 100 inches) allow for a different display experience than when using "smaller screens". This is dependent upon resolution and other technical parameters. Home cinema and fusing multiple display-operations will be possible. |
| Mass market deployment | After 2015 |
| Sub category | Direct-view |
| Related technology | Super-Hi Vision<br>2/4/8 k Home cinema projections |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>08 Avoid unintentional activation of controls<br>10 Have equivalent security and privacy<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any access features needed) |
| Accessibility barriers | - A large size display might be difficult to interact with due to the requirement of viewing content or controlling elements on a large display.<br>- Displayed content might not be accessible for people with visual impairments.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Display surfaces should be reachable by all users e.g. for people in wheelchairs.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: support flexible displayed information adjustment.<br>- User limitation compensation: the placement and reachability of the display should take into account the needs of all users, including wheelchair users and, where appropriate, young children.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | - Placement within a home, function as furniture/decoration and viewing habits might be culturally dependent. |
| Benefit for all users | - Enhanced viewing experience(s). |
| Benefits for older people and people with disabilities | - Possibility to potentially adapt display/content to special requirements. |
| Deployment pros | - Ability to collect multiple screens on one large display; possibility to have one central "monitor" for multiple applications and image generating systems. |
| Deployment cons | - Space needed for optimal viewing distance.<br>- Content production and content distribution needs to be scaled-up to the abilities of these displays, too. |
| Implementation requirements | None identified |
| Harmonization | - Formats and parameters for content production, distribution and viewing. |

**Table 6.13.10: Super-Hi Vision**

| Characteristic | Definition |
|---|---|
| Name | Super-Hi Vision |
| Description | The term (and the technology) is today rather "fuzzy" or visionary. Super-Hi Vision is generally expected to supersede the pixel resolution of HDTV by four times (or more). This will make it possible to display more details due to higher resolutions and/or have larger screens. Note that the term does not (at this stage) limit the different technologies that might be used to reach this "Super-Hi" vision. |
| Mass market deployment | After 2015 |
| Sub category | Direct-view |
| Related technology | Large displays ≥ 254 cm (≥100 in.)<br>2/4/8 k Home cinema projection |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>11 Not cause personal risk (e.g. seizure, etc.)<br>15 Ability to use their assistive technology (AT) to control the ICT<br>16 Cross Cutting Issues |
| Accessibility barriers | - A high resolution or large size display might be difficult to interact with due to the requirement of viewing content or controlling elements on such a display.<br>- Displayed content might not be accessible for people with visual impairments.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Display surfaces should be reachable by all users.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: support flexible displayed information adjustment.<br>- User limitation compensation: the placement and reachability of the display should take into account the needs of all users, including wheelchair users and, where appropriate, young children.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | - Placement within a home/viewing location, function as furniture/decoration and viewing habits might be cultural dependent. |
| Benefit for all users | - Enhanced viewing experience(s). |
| Benefits for older people and people with disabilities | - Possibility to adapt display/content to special requirements. |
| Deployment pros | - Ability to collect multiple screens/different types of visual information on one large display; possibility to have one central "monitor" for multiple applications and image generating systems. |
| Deployment cons | - Space needed for optimal viewing distance.<br>- Content production and content distribution needs to be scaled-up to the abilities of these displays, too. |
| Implementation requirements | - Content generation and distribution need to be standardized. |
| Harmonization | - Formats and parameters for content production, distribution and viewing. |

**Table 6.13.11: Mini-projectors**

| Characteristic | Definition |
|---|---|
| Name | Mini-projectors |
| Description | Mini-projectors (also known as hand-held projectors or pico-projectors) incorporate the functionality of an image projector in a handheld size device. |
| Mass market deployment | By 2012 |
| Sub category | Projection |
| Related technology | Object Adaptive Displays |
| User requirements | 01 Perceive visual information |
| Accessibility barriers | - Users with visual impairments may have problems to perceive the output of a mini-projector.<br>- Users with reduced visual acuity may have problems to perceive information, caused either by the geometric relationship between the projector and display surface, the visual distortion added by non-planar surfaces, or by the material the surface is made of.<br>- Users may have problems to perceive information due to lighting conditions.<br>- Users may have problems to perceive information due to tremor of the person who is handling the mini-projector. |
| Solutions related to accessibility barriers | - Use of algorithms responding to the geometric relationship between the projector and display surface in order to create more stable images (e.g. Smart keystone correction, tremor correction).<br>- Multimodal presentation: visual information also available in auditory and in tactile form.<br>- Sensors to gather geometry and texture information about the surrounding environment, allowing projection which is appropriate to the display surface.<br>- Orientation compensated intensities. |
| Cultural issues | - This technology enables suitable applications for mobile phones and other mass market hand-held devices. |
| Benefit for all users | - Ability to share visual content between multiple people on an ad-hoc basis.<br>- They are a suitable complement for mobile phones and other hand-held devices.<br>- They allow use of portable projectors in arbitrary environments (potentially Plug-and-Play projectors) |
| Benefits for older people and people with disabilities | - Applicable to Augmented and Alternative Communications (AAC). |
| Deployment pros | - Integrated into many consumer electronics or as stand-alone display component, many devices with (formerly only) a small screen now gain the ability to share images among multiple viewers. |
| Deployment cons | - Currently low projection luminance, contrast and resolution, thus limited usage in sunlight/outdoor is possible.<br>- Distortion resulting from projecting onto non-planar, irregular surfaces.<br>- Correction of effects caused by movement/tremor of user's hand. |
| Implementation requirements | - Improvement of battery/power-supply technology.<br>- Further improvements of display brightness, contrast and resolution. |
| Harmonization | - Adherence to standards on display accessibility and on accessibility to hand-held devices. |

**Table 6.13.12: Head-up displays (HUD)**

| Characteristic | Definition |
|---|---|
| Name | Head-up displays (HUD) |
| Description | A head-up display (HUD) is any transparent display that presents data without requiring users to look away from their usual viewpoints. Originating from cockpit interfaces the projection of required information directly into the user's line of vision is now is being used in cars. |
| Mass market deployment | By 2012 |
| Sub category | Projection |
| Related technology | Visual AR |
| User requirements | 01 Perceive visual information |
| Accessibility barriers | - Users may have problems to perceive foreground information on changing backgrounds.<br>- Users may have problems to perceive information in high workload situations. |
| Solutions related to accessibility barriers | - Robust rendering algorithms should be used to ensure that foreground information (including text) is perceivable (e.g. sufficient luminance and contrast) on changing backgrounds.<br>- Multimodal presentation: adding auditory and haptic/tactile signals to the visual modality to improve the perception of information, especially in high-workload situations. |
| Cultural issues | - Social concerns about driving security issues. |
| Benefit for all users | - When used in cars, reduces the number and duration of the driver's sight deviations from the road.<br>- Applicable to Commercial Vehicle Operation system.<br>- See-through augmenting or camera-overlaying with computer generated graphics; relevant visual information can be collected in one place/in field of sight. |
| Benefits for older people and people with disabilities | - Beneficial for users with mobility impairments, as no additional movement is required to look at the display. |
| Deployment pros | - Specific applications (e.g. driving).<br>- Augmenting of mobile phone/devices will see widespread application usage. |
| Deployment cons | - Safety concerns. |
| Implementation requirements | - Improvement of image luminance and contrast. |
| Harmonization | - Adherence to standards on accessibility of displays. |

**Table 6.13.13: Spatially immersive displays**

| Characteristic | Definition |
|---|---|
| Name | Spatially immersive displays (SID) |
| Description | Spatially immersive displays use large back-projected screens set at right angles (generally three walls and a floor), onto which stereo graphics are projected. The user wears stereo glasses and a head tracker. The tracker allows the 3D environment to be rendered from the user's point of view and allows users to move naturally to change their viewpoints. |
| Mass market deployment | By 2015 |
| Sub category | Projection |
| Related technology | Object adaptive displays<br>Wallpaper projections<br>Mini-projectors<br>Spatial AR |
| User requirements | 01 Perceive visual information |
| Accessibility barriers | - Users with visual impairments may not perceive partially or totally visual information. |
| Solutions related to accessibility barriers | - Multimodal presentation: haptic/tactile and auditory interfaces may be used to convey spatial information to a non-visual user. |
| Cultural issues | - Massive adoption questioned, as in addition to being expensive, these displays require a specific room to have the equipment installed.<br>- May be seen as a too invasive display for standard home environments. |
| Benefit for all users | - Realistic feeling of immersion. |
| Benefits for older people and people with disabilities | - Application to rehabilitation purposes. |
| Deployment pros | - SIDs produce excellent perceived immersion because of their high resolution, good stereo and wide field of view. |
| Deployment cons | - Most common SIDs do not provide complete physical immersion, since two sides of the six-sided cube are usually missing. In such displays, users cannot physically turn 360 degrees to perceive the virtual world around them.<br>- High costs.<br>- Room requirements. |
| Implementation requirements | - Immersive perception for people with visual impairments. |
| Harmonization | - Adhere to standards on display accessibility. |

**Table 6.13.14: Interactive floors**

| Characteristic | Definition |
|---|---|
| Name | Interactive floors |
| Description | This technology makes use of the floor as a projection area to display content. Interaction might be provided by different vision tracking systems or sensors embedded in the flooring. |
| Mass market deployment | By 2015 |
| Sub category | Projection |
| Related technology | Wallpaper projection<br>Ambient displays<br>(additional tracking or sensing/backchannel technologies likely) |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out all actions including maintenance and setup<br>07 Be able to complete actions and tasks within the time allowed<br>08 Avoid unintentional activation of controls<br>09 Be able to recover from errors<br>10 Have equivalent security and privacy<br>11 Not cause personal risk (e.g. seizure, etc.)<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any access features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT<br>16 Cross Cutting Issues |
| Accessibility barriers | - Floor might not be accessible for physical interaction.<br>- Displayed (multimedia) content should alternatively be able to be made available in a different media form. |
| Solutions related to accessibility barriers | None identified |
| Cultural issues | - Projecting images/animations/video on any (part) of the floor might not be acceptable. |
| Benefit for all users | - Usage of the floor as large, (interactive) display.<br>- Usage of lower extremities for input/interaction. |
| Benefits for older people and people with disabilities | - Usage (interaction) with and without arms (feet/full-body). |
| Deployment pros | - "Display" surface area can be varied in size/position. |
| Deployment cons | Might require special flooring materials.<br>- Usage of sensing/tracking technologies might be required.<br>- Modality details of interaction need to be developed or existing ones refined. |
| Implementation requirements | None identified |
| Harmonization | - Content, format and interaction might benefit from standardization. |

**Table 6.13.15: Head mounted displays**

| Characteristic | Definition |
|---|---|
| Name | Head mounted displays |
| Description | Head mounted displays (HMD) are a family of display/projection technologies which have in common that they are worn close to the eye. Visual content is displayed/projected into one (monocular HMD) or two eyes (binocular HMD), e.g. with help of lenses, semi-transparent micro-mirrors embedded in eye-glasses, a helmet or a visor. HWDs can be designed in optical see-through, opaque or video see-through modes. Different applications (from reading email to creating a truly immersive effect) will require different device characteristics, and therefore represent different technology requirements from the user's perspective. |
| Mass market deployment | By 2015 |
| Sub category | Projection |
| Related technology | Wearable immersive AR<br>Wearable see-through AR<br>Spatially immersive displays |
| User requirements | 01 Perceive visual information<br>11 Not cause personal risk |
| Accessibility barriers | - Users with visual impairments may have problems to perceive visual information displayed by HMD.<br>- Especially with opaque HMD, users might not be aware of obstacles or dangerous situations that are either not displayed by the system or not perceived by the users.<br>- While using see-through HMD, users might be distracted from other important (even vital) tasks such as driving. |
| Solutions related to accessibility barriers | - Multimodal presentation: visual information also available in auditory and tactile form.<br>- Robust rendering algorithms should be used to ensure that foreground information (including text) is perceivable (e.g. sufficient luminance and contrast) on changing backgrounds.<br>- Luminance and contrast should allow outdoor use for users with reduced visual acuity.<br>- When using opaque HMD, users should be alerted of potential risks in the environment. |
| Cultural issues | - Adoption of this technology will require light, portable and fashionable equipment. |
| Benefit for all users | - Privacy when accessing visual information.<br>- Applicability to augmented reality applications. |
| Benefits for older people and people with disabilities | - Assistive technology for supporting people with cognitive impairments and mental disorders, as well as for people on physical rehabilitation. |
| Deployment pros | - Unobtrusive display technology, especially where hands-free is required.<br>- For virtual reality applications involving navigation through enclosed spaces and frequent turning, HMDs provide increased efficiency and spatial orientation to users than spatially immersive displays. |
| Deployment cons | - Power consumption requires improvement of battery duration/power supply.<br>- Effects of misuse/abuse (e.g. for visual attention in real life situations).<br>- Low portability. |
| Implementation requirements | - Increase Field of View (FOV).<br>- More luminance (especially in outdoors, see-through applications).<br>- Higher resolution and head mobility.<br>- Tracking capabilities.<br>- More portable equipment allowing a better mobility of the head.<br>- Increased battery duration. |
| Harmonization | - Adherence to standards on accessibility of displays. |

**Table 6.13.16: Wallpaper projection**

| Characteristic | Definition |
|---|---|
| Name | Wallpaper projection |
| Description | This technology makes use of walls as large areas for projecting visual content, normally static images. |
| Mass market deployment | After 2015 |
| Sub category | Projection |
| Related technology | Object adaptive display |
| User requirements | 01 Perceive visual information |
| Accessibility barriers | - Users with visual impairments may have problems perceiving wallpaper projection.<br>- Environment conditions (e.g. shadows caused by persons or objects, changing light conditions) may make perception of visual information difficult.<br>- Distance from the user to the wall may influence the perception of the projected information.<br>- Curved walls may cause a distortion in the projected image (see Object adaptive displays, table 6.13.18, for further information). |
| Solutions related to accessibility barriers | - Multimodal presentation: visual information also available in auditory and tactile form.<br>- Using networks of overlapping projectors to fill in shadows.<br>- Automatic adaptation of the projection to changing lighting conditions to ensure that the visual information is perceivable.<br>- For solutions to distortion caused by curved surfaces, please refer to Object adaptive displays, table 6.13.18. |
| Cultural issues | - In order to become massively adopted, wallpaper projection technologies should be adopted by architects as part of building design.<br>- There might social concerns on what kind of images can be projected in certain places. |
| Benefit for all users | - This technology may support the display of information according to user location within the home/public space. |
| Benefits for older people and people with disabilities | - This technology may be used for supporting users in their daily living activities at home (e.g. emotional support) without requiring the use of specific equipment). |
| Deployment pros | - Wall-size displays provide large screen areas on which to show information.<br>- Suitable display for applications designed to support users in living environments. |
| Deployment cons | - Frequent changes in ambient light conditions in a standard home (people moving around, switching lights on-off, blinds up-down, etc.) may require complex settings of projectors and challenging projection features. |
| Implementation requirements | - Automatic control of projector networks.<br>- Tracking of user's position with respect to the projection. |
| Harmonization | - Adherence to standards on display accessibility. |

**Table 6.13.17: 2/4/8 k Home cinema projection**

| Characteristic | Definition |
|---|---|
| Name | 2/4/8 k Home cinema projection |
| Description | This display technology is currently only available in few research systems, and is very expensive and exclusive. However, the extreme resolution achievable is also very engaging as far as viewing experience is concerned. |
| Mass market deployment | After 2015 |
| Sub category | Projection |
| Related technology | Super-Hi Vision<br>Large monitors ≥ 254 cm (≥100 in.) |
| User requirements | 01 Perceive visual information |
| Accessibility barriers | None identified |
| Solutions related to accessibility barriers | None identified |
| Cultural issues | - Placement within a home/viewing location, function as furniture/decoration and viewing habits might be culturally dependent. |
| Benefit for all users | - Enhanced viewing experience(s). |
| Benefits for older people and people with disabilities | - Potential to adapt display/content to special requirements. |
| Deployment pros | - Ability to collect multiple screens on one large projection.<br>- Possibility to have one central "monitor" for multiple applications and image generating systems. |
| Deployment cons | - Space needed for optimal viewing (distance).<br>- Content production and content distribution also needs to be scaled-up to the abilities of these displays. |
| Implementation requirements | - Content provision/distribution is dependent upon suitable media or network connection/protocols. |
| Harmonization | - Formats and parameters for content production, distribution and viewing. |

**Table 6.13.18: Retinal projectors**

| Characteristic | Definition |
|---|---|
| Name | Retinal projectors |
| Description | A retinal projector, also known as retinal scan display, is a display technology (either based on LEDs or laser) that draws a raster display directly onto the retina of the eye. The effect is that the user sees the image floating in space in front of them. |
| Mass market deployment | After 2015 |
| Sub category | Projection |
| Related technology | Visual AR |
| User requirements | 01 Perceive visual information<br>11 Not cause personal risk |
| Accessibility barriers | - Users with visual impairments may have problems to perceive image from retinal projectors.<br>- Safety issues related to projecting a light beam into the eye. |
| Solutions related to accessibility barriers | - Multimodal presentation: visual information also available in auditory and tactile form.<br>- Adherence to standards (ANSI, IEC) addressing safety of projecting laser beams into the eye. |
| Cultural issues | None identified |
| Benefit for all users | - Applicable to virtual reality, as computer-generated images would be laid over user's view of real objects. |
| Benefits for older people and people with disabilities | - Applicable to virtual reality. |
| Deployment pros | - May be used as a display technology for handheld devices, as it suits the low-power requirements of mobile devices. |
| Deployment cons | - Complexity of tracking user's eye in motion when he/she is in motion. |
| Implementation requirements | - Advancement in pointing the beam (e.g. continuous face recognition techniques plus motion compensation). |
| Harmonization | - Adherence to standards on display accessibility.<br>- Adherence to standards (ANSI, IEC) addressing safety of projecting laser beams into the eye. |

**Table 6.13.19: Object adaptive projection**

| Characteristic | Definition |
|---|---|
| Name | Object adaptive projection |
| Description | Enhanced projectors that can determine and respond to the geometry of the display surfaces (e.g. home objects).<br>This can be used for displaying on surfaces with different shapes and 3D characteristics, object augmentation, etc. |
| Mass market deployment | After 2015 |
| Sub category | Projection |
| Related technology | Wallpaper projection<br>Spatial AR |
| User requirements | 01 Perceive visual information |
| Accessibility barriers | - Users may have problems to perceive information, caused by the visual distortion added by non-planar surfaces, by the material the surface is made of or by objects in the environment blocking projectors.<br>- Users may have problems in perceiving information due to changing light conditions. |
| Solutions related to accessibility barriers | - Sensors to gather geometry and texture information about the surrounding environment, allowing projection which is appropriate to the display surface.<br>- Smart keystone correction.<br>- Orientation compensated intensities.<br>- Using a grid of context-aware projectors.<br>- Automatic removal of shadows. |
| Cultural issues | - Visual interfaces can be embedded in objects from everyday life, allowing localisation of user interfaces to different cultures. |
| Benefit for all users | - The size of the projector can be much smaller than the size of the image it produces.<br>- Overlapping images from multiple projectors can be effectively superimposed on the display surface.<br>- Ability to include different objects (from small to building-size) as displays.<br>- Ability to create immersive display experiences (mixture of real physical world and artificially created/displayed content). |
| Benefits for older people and people with disabilities | - Display of content on surfaces suitable to user's specific needs. |
| Deployment pros | - Useful for displaying on surfaces with different shapes and 3D characteristics, object augmentation, etc.<br>- The display surface does not need to be planar or rigid, allowing augmentation, many types of surfaces and merging projected images with the real world. |
| Deployment cons | - Frequent changes in ambient light conditions in a standard home (people moving around the home, switching lights on-off, blinds up-down, etc.).<br>- Shadows produced by either people or objects.<br>These systems may need a significant calibration process prior to being used.<br>- Affected by the properties of the object (reflectance of the surface, shape, etc.). |
| Implementation requirements | - Automatic adaptation to the environment (e.g. lighting conditions, shadows, changing surfaces where the image is projecting on). |
| Harmonization | - Adhere to standards on display accessibility. |

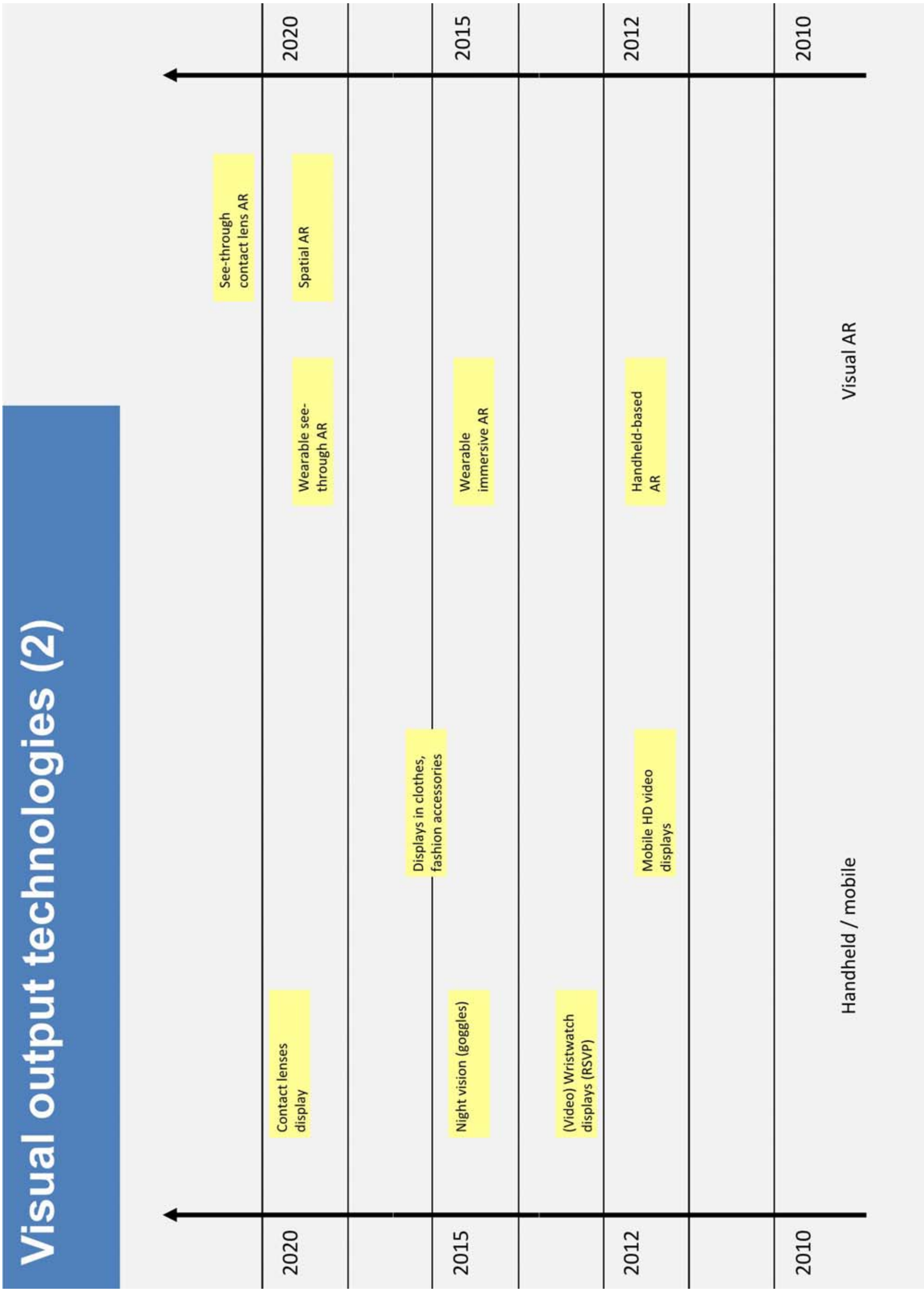


**Figure 6.13.2: Visual output technologies roadmap (2)**

Handheld/mobile displays are widely used today and are foreseen to see further refinements, especially in combination with other technologies (e.g. electronic paper technologies), modalities (e.g. touch and multi-touch input) or as given below, in combinations with Visual AR. The key developments in the area of handheld/mobile displays as visual output technologies are:

- ability to see media content in full HD resolution;
- displays becoming part of clothes or displays integrated as (fashion) accessories;
- ability to display/see in lighting conditions that were previously considered to be too dark;
- displays being worn close to the eye, e.g. as contact lens displays.

Such handheld/mobile visual output technologies can become enablers for people with different (visual) impairments as the identified technologies provide features such as the ability to use the increased resolution to allow display settings better adapted to their needs. Furthermore, visual assistance can be used and worn in less obvious ways (e.g. as a wristwatch or as part of clothing).

Identified problems for all users, and especially users with (visual-) impairments, may consist of:

- handheld/mobile displays may not be accessible at all, or only partially accessible to people with visual impairments;
- novel visual output technologies might not provide the content or control in any other modality than by using the visual channel;
- visually impaired users may find it difficult to identify controls (e.g. the on/off control) and indications (e.g. status of device, transmitting or idle).

Solutions for these and other accessibility barriers are listed in the tables 6.13.19 to 6.13.23 and include, for handheld/mobile display technologies:

- multimodal controls and indications offering access to a device or eService by means of more than one sensory modality;
- provision of multimodal presentation of visual content as an alternative option;
- ensuring connectivity to assistive devices;
- reduced complexity modes ensuring that important and/or critical functionality is easily accessible by all users including those with severe impairments.

Augmented Reality (AR) displays are those in which the image is of a primarily real environment, which is enhanced, or augmented, with computer-generated imagery [Milgram et al, 1994]. AR technologies have the potential to provide significant benefits in many application areas, mainly based on their ability to support users' interaction with a physical context which is enhanced by information and resources in meaningful locations within the user's visual field [Kooper & MacIntyre, 2003]. Displayed information includes textual annotations, directions, graphics, instructions, as well as more specific applications such as Obscure Information Visualization (OIV), which shows objects that are physically present, but occluded.

AR technologies identified within the present clause correspond to the different contexts where the combination of real images and computer-generated images is displayed to the user, namely: a hand-held device, a wearable immersive device, a wearable see-through device (i.e. glasses and contact lenses) and the space around the user.

Main accessibility barriers for using these technologies have to do with:

- perception of visual (real and computer generated) information by users with visual impairments, including people who can only see with one eye, people who are colour blind, people with reduced visual acuity, etc.;
- problems in interpreting augmented information;
- safety problems caused either by users being distracted from other important tasks, or by user's immersion in a virtual world which is not allowing perception of dangerous situations taking place in the surrounding real world.

Solutions to these barriers are listed in the tables 6.13.24 to 6.13.28 and include:

- consistent integration of visual AR with other interaction modalities (e.g. audio, haptic/tactile);
- using robust rendering algorithms to ensure that foreground information is perceivable on changing backgrounds;
- allowing users to configure display characteristics, including the selection of perceptual cues used to eliminate depth/perception ambiguity;
- providing clear instructions on when this technology can be used and when not;
- alerting users of immersive systems to potential risks in the real environment;
- supporting users to distinguish clearly which part of the information being displayed is not real.

People considering the use of the type of visual output technologies covered in this clause in ICT devices and services can find additional useful insights and information in the following sources: [Milgram et al, 1994], [Kooper & MacIntyre, 2003] (generic information on AR and its applications); [Zhou et al, 2004], [Ahmaniemi & Lantz, 2009] (complementing AR with other user interaction modalities); [Gabbard et al, 2007] (perception of foreground information on changing backgrounds); [Furmanski, Azuma & Daily, 2002] (user experience in Obscure Information Visualization (OIV) applications), [Parviz, 2009] (AR in contact lenses).

Table 6.13.20 gives an alphabetical listing of the technologies covered in this clause.

**Table 6.13.20: Overview of visual output technologies (2)**

| User interaction technology | Sub category | Table |
|---|---|---|
| Contact lens displays | Handheld/mobile | 6.13.25 |
| Displays in clothes, fashion accessories | Handheld/mobile | 6.13.24 |
| Handheld-based AR | Visual AR | 6.13.26 |
| Mobile HD video displays | Handheld/mobile | 6.13.21 |
| Night vision (goggles) | Handheld/mobile | 6.13.23 |
| See-through contact lenses AR | Visual AR | 6.13.30 |
| Spatial AR | Visual AR | 6.13.29 |
| (Video-) Wristwatch displays (RSVP) | Handheld/mobile | 6.13.22 |
| Wearable immersive AR | Visual AR | 6.13.27 |
| Wearable see-through AR | Visual AR | 6.13.28 |

**Table 6.13.21: Mobile HD video displays**

| Characteristic | Definition |
|---|---|
| Name | Mobile HD video displays |
| Description | Mobile (smart/phone) and similar devices having the display resolution of full HD video. |
| Mass market deployment | By 2012 |
| Sub category | Handheld/mobile |
| Related technology | Mini-projectors |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- High resolution makes graphical elements difficult to interact with if the resolution is used to create very small or fine detailed control elements. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: support flexible displayed information adjustment. |
| Cultural issues | - Mobile HD-Video watching (in public places) might not be appropriate due to cultural customs or circumstances. |
| Benefit for all users | - Display of HD video.<br>- Good readability of content. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - Provision/distribution of HD video to mobile clients. |
| Deployment cons | - Network bandwidth and quality of service needs to be sufficient for transmission of HD video.<br>- Currently schemes for HD video service or data traffic have a prohibitive cost. |
| Implementation requirements | - Processing power and battery/power supply need to be sufficient to view HD video for an appropriate time duration. |
| Harmonization | None identified |

**Table 6.13.22: (Video-) Wristwatch displays (RSVP)**

| Characteristic | Definition |
|---|---|
| Name | (Video-) Wristwatch displays (RSVP) |
| Description | Wearable displays enabled to show content on a small screen worn like a wristwatch. It is likely that dynamic display strategies such as Rapid Serial Visual Presentation (RSVP) will be used to display media content larger than the screen. This kind of wristwatch display can have multiple purposes, serving as stand-alone application or enabling services in combination with other ICT devices and services. |
| Mass market deployment | By 2015 |
| Sub category | Handheld/mobile |
| Related technology | Displays in clothes, fashion accessories |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out actions including maintenance and setup<br>07 Be able to complete actions and tasks within the time allowed<br>08 Avoid unintentional activation of controls<br>11 Not cause personal risk (e.g. seizure, etc.)<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any accessibility features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed visual information should be made available in a different, non-visual form.<br>- Dangerous blinking frequencies should be avoided and users should be allowed to turn them off when they occur.<br>- Displayed content might not be accessible for people with visual impairments.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Control elements should be operational by all users.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Display speeds (e.g. for RSVP) should be adjustable by the user.<br>- Re-play function should be implemented.<br>- Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- User limitation compensation: the placement and reachability of the control elements should take into account the needs of all users.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | - Wristwatch displays (e.g. for wearable alarms) may be seen as stigmatizing older users.<br>- Wearable displays might be seen as jewellery and therefore need to be designed accordingly (e.g. for different genders, "disguised" as watches). |
| Benefit for all users | - Light-weight, wearable display technology. |
| Benefits for older people and people with disabilities | - Display might be coupled with other technologies e.g. sensing or alarm. |
| Deployment pros | - Dynamic display allows information that would (in static form) not fit onto the display screen to be shown. |
| Deployment cons | - Reading comprehension might be impaired, i.e. visual content (alphanumeric/symbolic) might not be legible. |
| Implementation requirements | None identified |
| Harmonization | - Standardized interfaces with (video-) wristwatches, covering display formats and RSVP strategies. |

**Table 6.13.23: Night vision (goggles)**

| Characteristic | Definition |
|---|---|
| Name | Night vision (goggles) |
| Description | Different technologies (image intensification, thermal imaging or active illumination) enable humans to see in low lightning conditions where one would not be able to see something without technical aids. |
| Mass market deployment | By 2015 |
| Sub category | Handheld/mobile |
| Related technology | Head-up displays (HUD)<br>Low light cameras |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out actions including maintenance and setup<br>08 Avoid unintentional activation of controls<br>11 Not cause personal risk (e.g. seizure, etc.)<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any accessibility features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Control elements should be operational by all users.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Multimodal feedback: feedback from user operations should be presented in multiple modes.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | - Night vision (goggles) usage might not be appropriate or acceptable due to cultural customs or circumstances such as privacy (potentially watching others who are not aware of being watched). |
| Benefit for all users | - Provision of night vision, visual enhancement in low-lightening conditions. |
| Benefits for older people and people with disabilities | - The ability to communicate in difficult/dark light situations using sign language. |
| Deployment pros | - Ability to visually signal even in low-lightening conditions. |
| Deployment cons | - Some people may feel that their privacy can be invaded more easily.<br>- Potentially harmful if sudden changes to bright light are encountered (safety). |
| Implementation requirements | - Enhanced (light amplified) scene will probably be difficult to be make available in a different, non-visual form.<br>- Sudden changes in viewed light should not lead to a blinding reaction; health hazard needs to be investigated. |
| Harmonization | None identified |

**Table 6.13.24: Displays in clothes, fashion accessories**

| Characteristic | Definition |
|---|---|
| Name | Displays in clothes, fashion accessories |
| Description | Different display technologies that allow the integration into clothes or in/as fashion accessories. The importance with these displays is in the "look and feel" more than in the display-technology characteristics ("fashion accessories"). It is therefore expected that non-functional parameters and attributes are more important than functional ones regarding the display technology's attributes. |
| Mass market deployment | After 2015 |
| Sub category | Handheld/mobile |
| Related technology | Colour electronic-paper displays<br>Flexible electronic-paper displays<br>Ambient displays |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out actions including maintenance and setup<br>08 Avoid unintentional activation of controls<br>11 Not cause personal risk (e.g. seizure, etc.)<br>13 Understand how to use product (including discovery and activation of any accessibility features needed)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Dangerous blinking frequencies should be avoided and users should be allowed to turn them off.<br>- If the display of content is important, it might not be accessible for people with visual impairments.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Control elements should be operational by all users.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Blinking frequencies, intensities and colour settings might need to be adjustable.<br>- Multimodal presentation: provide multimodal presentation where relevant.<br>- Multimodal control: allow for multimodal control of the device.<br>- User limitation compensation: the placement and reachability of the control elements should take into account the needs of all users.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | - Due to the notion of "fashion" this technology might be highly sensitive to cultural acceptance.<br>- Cultural offending content displayed may vary according to context. The wearer might not be aware of such a change in settings.<br>- Visual attraction/distraction might not be acceptable. |
| Benefit for all users | - Low-level of attention usage of display technology - novel usages might be envisioned for different (social, functional) activities.<br>- Worn displays can indicate and communicate between a wearer and another (worn/permanent) ICT device or service that senses or communicates with the worn display e.g. an authentication before being allowed to enter a secured place. |
| Benefits for older people and people with disabilities | - Possibility to display - in visual form - information that cannot be given by other means of expression. |
| Deployment pros | - Multiple displays are possible for dedicated purposes and placements as part of the clothing/fashion statement. Assistive technology could be disguised as part of an item of clothing. |
| Deployment cons | - Disturbing attention-grabbing visual signals ("blinking") for observers.<br>- Possible interference (e.g. reflections) with activities that require dark surrounding (for eye adaptation/night sight), e.g. driving a car/steering a boat at night. |
| Implementation requirements | - Power-supply/generation and power-consumption need to be appropriate to the usage application.<br>- Possible requirement of washing/clearing needs to be solved.<br>- Disposing/recycling of used materials needs to be ensured.<br>- Unclear durability of displays (based upon technology applied) needs to be addressed. |
| Harmonization | - Potential need for legislation to regulate usage for safety and health-hazard reasons. |

**Table 6.13.25: Contact lens displays**

| Characteristic | Definition |
|---|---|
| Name | Contact lens displays |
| Description | Contact lenses can be used to generate visual signals that can be used as a display. |
| Mass market deployment | After 2015 |
| Sub category | Handheld/mobile |
| Related technology | None identified |
| User requirements | 01 Perceive visual information<br>06 Be able to invoke and carry out actions including maintenance and setup<br>08 Avoid unintentional activation of controls<br>11 Not cause personal risk (e.g. seizure, etc.)<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any accessibility features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Placement into/removal from the eye requires fine-motoric ability that older people and people with disabilities might not have.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Control elements should be operational by all users. |
| Solutions related to accessibility barriers | - User limitation compensation: in placement and reachability of control elements.<br>Multimodal control: allow for multimodal control of the device. |
| Cultural issues | - Quasi-bionic enhancements might not be acceptable to all potential users. |
| Benefit for all users | - Unobtrusive, wearable display close to the eye. |
| Benefits for older people and people with disabilities | - Possibility to display visual information with low spatial and temporal resolution, possibly texts, or navigational aids. |
| Deployment pros | - No physical screen required to display visual information.<br>- Low power requirements to produce a visual signal. |
| Deployment cons | - Placement into/removal from the eye requires fine-motoric ability.<br>- Very low resolution in very few research systems currently state-of-the-art. |
| Implementation requirements | - Miniaturization and power supply needs to be solved (as the use of batteries is likely to be impossible).<br>- RF-, solar- or vibration-generated power supply might be necessary.<br>- Materials that are in contact with the eye should be biocompatible. |
| Harmonization | - Biocompatibility (health-safety) needs be ensured. |

**Table 6.13.26: Handheld-based AR**

| Characteristic | Definition |
|---|---|
| Name | Handheld-based AR |
| Description | The user sees computer generated information on their handheld device, complementing/augmenting the real context. |
| Mass market deployment | By 2012 |
| Sub category | Visual AR |
| Related technologies: | Wearable immersive AR<br>Wearable see-through AR<br>See-through contact lenses AR |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>11 Not cause personal risk<br>14 Understanding the output or displayed material (even after users perceive it accurately) |
| Accessibility barriers | - Users with visual impairments, including people who can only see with one eye and people who are colour blind, may be unable to perceive augmented visual information.<br>- While using these systems, users might be distracted from other important (even vital) tasks such as driving.<br>- Users may have problems to interpret augmented information. |
| Solutions related to accessibility barriers | - Multimodal presentation: visual information also available in auditory and tactile form.<br>- Multimodal presentation: the addition of 3D sound helps depth perception, task performance and facilitates collaborations between users.<br>- Displayed information adjustability: rendering should be configurable to ensure that information is perceivable by users with visual impairments (e.g. including people who can only see with one eye and people who are colour blind).<br>- Displayed information adjustability: users should be able to select perceptual cues (e.g. motion parallax, binocular clues or size-constancy/scaling) used to eliminate depth/perception ambiguity.<br>- Multimodal control: when the use of markers (e.g. in the surroundings, in a catalogue) is required to operate the system, other accessible alternatives should be considered for people with visual impairments.<br>- Unneeded motion of rendered material should be eliminated (e.g. the slowly moving self-organization of rendered AR tags).<br>- Luminance and contrast should allow outdoor use, even in the case of people with reduced visual acuity.<br>- Robust rendering algorithms should be used to ensure that foreground information (including text) is perceivable (e.g. sufficient luminance and contrast) on changing backgrounds.<br>- Barrier-free user education: clear instructions should be provided about when this technology can be used and when not.<br>- Consistency with expectations: proper motion physics should be used for modelling the environment and moving objects.<br>- Consistency with expectations: a rule space should be defined. For instance, Obscured Information Visualization (OIV) applications should properly define conditions under which augmented information should be displayed. |
| Cultural issues | - Adoption of this technology may be influenced by laws and social attitudes about the use of navigational support systems (e.g. when driving). |
| Benefits of all users: | - Offering visual cues from a navigation system.<br>- Visualization of location bound information. |
| Benefits for older people and people with disabilities | - Applications supporting people with hearing and cognitive impairments (e.g. assisted navigation). |
| Deployment pros | - Many different applications for mobile phones. |
| Deployment cons | - Additional information on mobile phones might distract users from important tasks requiring their attention (walking, driving). |
| Implementation requirements | None identified |
| Harmonization issues: | - This technology should adhere to standards on display accessibility and mobile phones accessibility. |

**Table 6.13.27: Wearable immersive AR**

| Characteristic | Definition |
|---|---|
| Name | Wearable immersive AR |
| Description | The user sees both real world and computer-generated information through a wearable, head mounted display, operating in either opaque or video see-through modes. |
| Mass market deployment | By 2015 |
| Sub category | Visual AR |
| Related technologies: | Handheld-based AR<br>Wearable see-through AR<br>See-through contact lenses AR |
| User requirements | 01 Perceive visual information<br>11 Not cause personal risk<br>14 Understanding the output or displayed material (even after users perceive it accurately) |
| Accessibility barriers | - Users with visual impairments, including people who can only see with one eye and people who are colour blind, may be unable to perceive augmented visual information.<br>- Users might not be aware of obstacles or dangerous situations that are either not displayed by the system or not perceived by the users.<br>- Users may have problems interpreting augmented information. |
| Solutions related to accessibility barriers | - Multimodal presentation: visual information also available in auditory and tactile form.<br>- Multimodal presentation: the addition of 3D sound helps depth perception, task performance, facilitates collaborations between users and enables a more realistic and immersive feeling.<br>- Displayed information adjustability: rendering should be configurable to ensure that information is perceivable by users with visual impairments (e.g. including people who can only see with one eye and people who are colour blind).<br>- Displayed information adjustability: users should be able to select which perceptual cues (e.g. motion parallax, binocular clues or size-constancy/scaling) to be used to eliminate depth/perception ambiguity.<br>- Unneeded motion of rendered material should be eliminated (e.g. the slowly moving self-organization of rendered AR tags).<br>- Robust rendering algorithms should be used to ensure that foreground information (including text) is perceivable (e.g. sufficient luminance and contrast) on changing backgrounds.<br>- Users should be alerted of potential risks in the real environment, as well as when leaving the environment where virtual support is provided.<br>- Users should be supported to distinguish clearly when the system is on (e.g. reality being augmented) and when it is off, as well as which part of the information being displayed is not real.<br>- Consistency with expectations: proper motion physics should be used for modelling the environment and moving objects.<br>- Consistency with expectations: a rule space should be defined. For instance, Obscured Information Visualization (OIV) applications should properly define conditions under which augmented information should be displayed. |
| Cultural issues | - Adoption of this technology will require light, portable and fashionable equipment. |
| Benefits of all users: | - Application in educational and training services.<br>- Application in entertainment and gaming applications. |
| Benefits for older people and people with disabilities | - Rehabilitation for people with cognitive and/or motor impairments. |
| Deployment pros | - Applications in different areas. |
| Deployment cons | - The need for a room for the immersive experience to take place.<br>- Bulky displays. |
| Implementation requirements | - Light and portable equipment. |
| Harmonization issues: | - This technology should adhere to standards on display accessibility. |

**Table 6.13.28: Wearable see-through AR**

| Characteristic | Definition |
|---|---|
| Name | Wearable see-through augmented reality |
| Description | The user sees both real world and computer-generated information through a wearable, head mounted display, designed in optical see-through (e.g. glasses). |
| Mass market deployment | After 2015 |
| Sub category | Visual AR |
| Related technologies: | Handheld-based AR<br>Wearable immersive AR<br>See-through contact lenses AR<br>Head mounted displays |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>11 Not cause personal risk<br>14 Understanding the output or displayed material (even after users perceive it accurately) |
| Accessibility barriers | - Users with visual impairments, including people who can only see with one eye and people who are colour blind, may be unable to perceive augmented visual information.<br>- While using these systems, users might be distracted from other important (even vital) tasks such as driving.<br>- Users may have problems to interpret augmented information. |
| Solutions related to accessibility barriers | - Multimodal presentation: visual information also available in auditory and tactile form.<br>- Multimodal presentation: the addition of 3D sound helps depth perception, task performance and facilitates collaborations between users.<br>- Displayed information adjustability: rendering should be configurable to ensure that information is perceivable by users with visual impairments (e.g. including people who can only see with one eye and people who are colour blind).<br>- Displayed information adjustability: users should be able to select which perceptual cues (e.g. motion parallax, binocular clues or size-constancy/scaling) to be used to eliminate depth/perception ambiguity.<br>- Unneeded motion of rendered material should be eliminated (e.g. the slowly moving self-organization of rendered AR tags).<br>- Luminance and contrast should allow outdoors use to people with reduced visual acuity.<br>- Robust rendering algorithms should be used to ensure that foreground information (including text) is perceivable (e.g. sufficient luminance and contrast) on changing backgrounds.<br>- Multimodal control: when the use of markers (e.g. in the surroundings, in a catalogue) is required to operate the system, other accessible alternatives should be considered for people with visual impairments.<br>- Clear instructions should be provided on when this technology can be used and when not.<br>- Users should be allowed to distinguish clearly when the reality is being augmented and when it is not, as well as which part of the information being displayed is not real.<br>- Consistency with expectations: proper motion physics should be used for modelling the environment and moving objects.<br>- Consistency with expectations: a rule space should be defined (e.g. Obscured Information Visualization, OIV, applications should properly define conditions under which augmented information should be displayed). |
| Cultural issues | - Adoption of this technology will require light, portable and fashionable equipment. |
| Benefits of all users: | - Offering visual cues from a navigation system.<br>- Visualization of location bound information.<br>- No need to carry a display to visualize AR information.<br>- Privacy when accessing AR information. |
| Benefits for older people and people with disabilities | - Applications supporting people with hearing and cognitive impairments (e.g. assisted navigation). |
| Deployment pros | - Potentially, this technology represents a replacement for several UI components of current mobile devices (similarly to what already has happened with hands-free operation of mobile phones). |
| Deployment cons | - The current generation of see-through devices has a field of view of no more than 25 degrees and are not daylight compatible.<br>- Other features to be further developed: resolution, battery power and weight. |

| Characteristic | Definition |
| --- | --- |
| Implementation requirements | - Increasing field of view.<br>- Improving features for outdoors use, resolution, battery power and weight. |
| Harmonization issues: | - This technology should adhere to standards on display accessibility. |

### Table 6.13.29: Spatial AR

| Characteristic | Definition |
| --- | --- |
| Name | Spatial AR |
| Description | Visual augmented information is projected onto user's environment (e.g. objects, walls), rather than displayed in equipment handled or worn by the user. |
| Mass market deployment | After 2015 |
| Sub category | Visual AR |
| Related technology | Object adaptive displays<br>Mini-projectors<br>Handheld-based AR<br>Wearable immersive AR<br>Wearable see-through AR<br>See-through contact lenses AR |
| User requirements | 01 Perceive visual information<br>14 Understanding the output or displayed material (even after users perceive it accurately). |
| Accessibility barriers | - Users with visual impairments, including people who are colour blind, may be unable to perceive augmented visual information.<br>- Users may have problems to interpret augmented information. |
| Solutions related to accessibility barriers | - Multimodal presentation: visual information also available in auditory and tactile form.<br>- Multimodal presentation: the addition of 3D sound helps depth perception, task performance, facilitates collaborations between users and enables a more realistic and immersive feeling.<br>- Display of information to be accommodated to human visual sensitivity (e.g. luminance, contrast, focus).<br>- Robust algorithms should be used to ensure that foreground information (including text) is perceivable on object's surface.<br>- The display of AR information should be designed for outdoors use.<br>- Users should be allowed to distinguish clearly when the reality is being augmented and when it is not, as well as which part of the information being displayed is not real. |
| Cultural issues | None identified |
| Benefit for all users | - Augmentation of objects around the user.<br>- Allows for wide area, high resolution.<br>- Reduces the need for the user to handle or wear equipment. |
| Benefits for older people and people with disabilities | - Applications supporting people with cognitive impairments. |
| Deployment pros | - The size of the image projectors can be much smaller than the size of the image itself.<br>- Overlapping images from multiple projectors can be effectively superimposed on the display surface. |
| Deployment cons | - Frequent changes in ambient light conditions in a standard home (people moving around the home, switching lights on-off, blinds up-down, etc.).<br>- Shadows produced by either householders or objects.<br>- Affected by the properties of the object (reflectance of the surface, shape, etc.).<br>- Limited depth of field of projectors. |
| Implementation requirements | - Ensure high view fidelity.<br>- Fitting shapes and characteristics of objects.<br>- Accurate colours.<br>- Tracking users and moving objects. |
| Harmonization | - Adherence to standards on display accessibility. |

**Table 6.13.30: See-through contact lenses AR**

| Characteristic | Definition |
|---|---|
| Name | See-through contact lenses AR |
| Description | The user sees directly the real world, which is enhanced, or augmented, with computer-generated imagery displayed in contact lenses worn by the user. These lenses are polymers integrating LEDs, control and communication circuits, as well as miniature antennas. Antennas and circuits are integrated through optoelectronic components. It is likely that a separate, portable device will control the rendering of visual information. |
| Mass market deployment | After 2015 |
| Sub category | Visual AR |
| Related technologies: | Handheld-based augmented reality<br>Wearable immersive augmented reality<br>See-through glasses VR systems<br>Contact lens displays |
| User requirements | 01 Perceive visual information<br>11 Not cause personal risk<br>14 Understanding the output or displayed material (even after users perceive it accurately) |
| Accessibility barriers | - Users with visual impairments, including people who can only see with one eye and people who are colour blind, may be unable to perceive augmented visual information.<br>- The display may move around relatively to the pupil.<br>- Normally, eyes cannot focus on objects that are less than 10 centimetres from the corneal surface.<br>While using these systems, users might be distracted from other important (even vital) tasks such as driving.<br>- Most red LEDs are made of aluminium gallium arsenide, which is toxic.<br>- Wireless signals may not be safe for the user.<br>- Users may have problems interpreting augmented information. |
| Solutions related to accessibility barriers | - Multimodal presentation: visual information also available in auditory and tactile form.<br>- Displayed information adjustability: rendering should be configurable to ensure that information is perceivable by users with visual impairments (e.g. including people who can only see with one eye and people who are colour blind).<br>- Displayed information adjustability: users should be able to select which perceptual cues (e.g. motion parallax, binocular clues or size-constancy/scaling) to be used to eliminate depth/perception ambiguity.<br>- Unneeded motion of rendered material should be eliminated (e.g. the slowly moving self-organization of rendered AR tags).<br>- Luminance and contrast should allow outdoors use.<br>- Robust rendering algorithms should be used to ensure that foreground information (including text) is perceivable (e.g. sufficient luminance and contrast) on changing backgrounds.<br>- Lenses should be weighted on the bottom to maintain a specific orientation (like in contact lenses that correct for astigmatism).<br>- Arrays of smaller lenses placed on the surface of the contact lens to help the eyes to focus the computerized information.<br>- Users should be allowed to distinguish clearly when the reality is being augmented and when it is not, as well as which part of the information being displayed is not real.<br>- Proper motion physics should be used for modelling the environment and moving objects.<br>- A rule space should be defined. For instance, Obscured Information Visualization (OIV) applications should properly define conditions under which augmented information should be displayed. |
| Cultural issues | None identified |
| Benefits of all users: | - No need to carry a display to visualize AR information.<br>- Privacy when accessing AR information. |
| Benefits for older people and people with disabilities | - These systems may provide visual augmented information supporting people with hearing or cognitive impairments. |
| Deployment pros | - Having the light emitter on a user's pupil requires little power to ensure that it is perceivable. |
| Deployment cons | - Lens's parts and subsystems are currently incompatible with one another and with the fragile polymer of the lens.<br>- All the components of the lens need to be miniaturized and integrated onto a flexible, transparent polymer. |

| Characteristic | Definition |
| --- | --- |
| Implementation requirements | - Hardware integrated in the lens should be transparent enough so that users can perceive the surroundings.<br>- Materials used in manufacturing the lens should be safe for the eye. Potential solutions include enveloping problematic components in a biocompatible substance.<br>- Pixels should be smaller, higher in contrast and capable of reacting quickly to external signals.<br>- Powering mobile communication components within the lens, as well as ensuring that wireless technology are safe for users. |
| Harmonization issues: | - This technology should adhere to standards on display accessibility. |

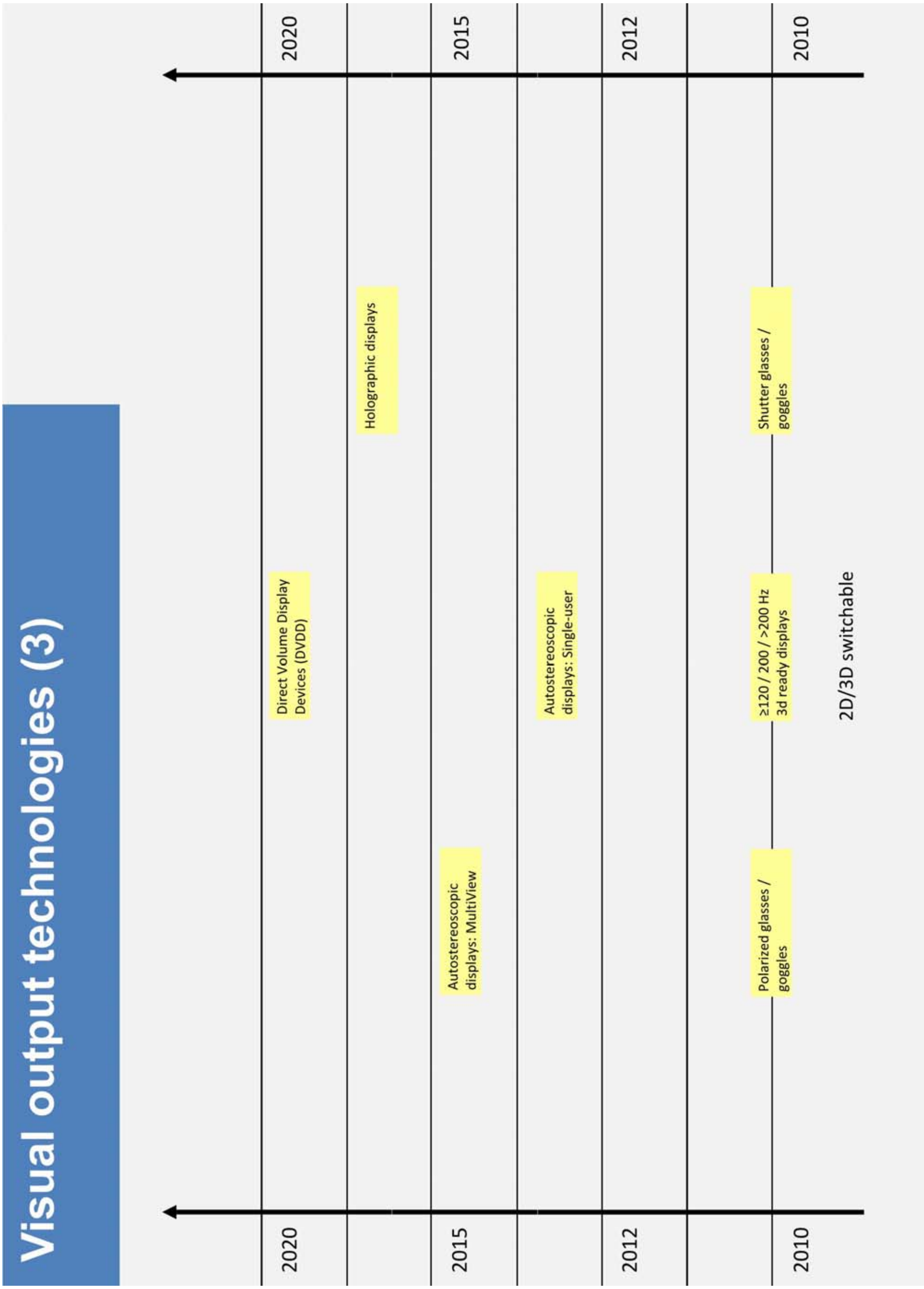


**Figure 6.13.3: Visual output technologies roadmap (3)**

2D/3D switchable visual output technologies are currently (2010) becoming a mass market consumer technology, mainly in the form of ≥ 120 Hz (LCD) displays in combination with (required) polarized or shutter glasses to view 3D content. While these technologies are seeing quick and widespread user take-up, 2D/3D switchable visual output technologies that will work without additional glasses (autostereoscopic displays) for single or even multiple viewers are still some years off, despite some selected systems being available.

Other types of systems are even more experimental at this stage, but may become available in the foreseen time-span of 10 years. Holographic displays as well as Direct Volume Display Devices (DVDD) may sound more like science fiction today, but they are attempts to solve known problems.

The key developments in the area of 2D/3D switchable, visual output technologies are:

- ability to show 3D content (but be compatible to 2D content) without the need for additional worn glasses i.e. as autostereoscopic displays;
- improved viewing experience through the immersion in the shown 3D content.

2D/3D switchable displays and their current development into mass market devices can be limiting and may cause problems for all users as well as for users with (visual-) impairments. Problems include:

- between 6-12 % of the general population is believed to have impoverished binocular vision to the extent that they are unable to experience 3D content on 2D/3D switchable displays;
- the 2D (compatibility) fall-back mode might be experienced as inferior in picture quality;
- long-term effects, especially with young children still developing 3D (real-world) visual cue interpretation, is still debated;
- motion sickness and headaches have been reported in combination with 3D content viewing;
- visually impaired users may find it difficult to identify controls (e.g. location of on/off) and indications (e.g. status of device, transmitting or idle), or interact with within the (sensed) 3D interaction modalities (e.g. through gestures).

Solutions for these and other accessibility barriers identified for individual or several visual output technologies are listed in the tables 6.13.29 to 6.13.35 and include:

- fall-back (backwards compatibility) to 2D content viewing;
- multimodal controls and indications offering access to a device or eService by means of more than one sensory modality;
- provision of multimodal presentation of visual content as an alternative option;
- ensuring connectivity to assistive devices.

Table 6.13.31 gives an alphabetical listing of the technologies covered in this clause.

**Table 6.13.31: Overview of visual output technologies (3)**

| User interaction technology | Sub category | Table |
|---|---|---|
| ≥ 120/200/≥ 200 Hz displays | 2D/3D switchable | 6.13.33 |
| Autostereoscopic displays: MultiView | 2D/3D switchable | 6.13.36 |
| Autostereoscopic displays: Single-User | 2D/3D switchable | 6.13.35 |
| Direct Volume Display Devices (DVDD) | 2D/3D switchable | 6.13.38 |
| Holographic displays | 2D/3D switchable | 6.13.37 |
| Polarized glasses/goggles (Stereoscopic display) | 2D/3D switchable | 6.13.32 |
| Shutter glasses/goggles | 2D/3D switchable | 6.13.34 |

**Table 6.13.32: Polarized glasses/goggles**

| Characteristic | Definition |
|---|---|
| Name | Polarized glasses/goggles (Stereoscopic display) |
| Description | Stereoscopic display requiring polarized glasses use a time-multiplexed polarization (i.e., the polarization is switched rapidly for successive frames); the polarized glasses ensure that each eye receives the appropriate image, thus producing the stereoscopic effect. |
| Mass market deployment | By 2012 |
| Sub category | 2D/3D switchable |
| Related technology | Shutter glasses/goggles<br>Autostereoscopic displays: Single-user<br>Autostereoscopic displays: Multi-view |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out all actions including maintenance and setup<br>07 Be able to complete actions and tasks within the time allowed<br>08 Avoid unintentional activation of controls<br>09 Be able to recover from errors<br>11 Not cause personal risk (e.g. seizure, etc.)<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any accessibility features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- 3D visual effect might not be experienced by part of the user population.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Handling of glasses/goggles might pose a problem for some impaired users.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- User limitation compensation: glasses/goggles ought to provide for ergonomic fit and/or the ability to adapt to individual wearers as users might not be able to readjust the glasses themselves.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | None identified |
| Benefit for all users | - 3D impressions give a heightened viewing experience. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - One of the cheapest solutions for 3D viewing.<br>- Available products already being offering in 2010. |
| Deployment cons | - Stereovision (eyesight ability) is a prerequisite to perceiving 3D display effects.<br>- Unclear health-risks (headache, nausea, consequences for young children's visual perception).<br>- Polarization can be effected by viewers' head position (angle of tilt). |
| Implementation requirements | - ≥ 120 Hz TV/projector, polarized glasses and media distribution or encoder providing the time-multiplexed polarised image is necessary. |
| Harmonization | - Possible health risks are currently not clear or its extent is not yet fully understood. A framework for these possible risks needs to be investigated. |

**Table 6.13.33: ≥ 120/200/≥ 200 Hz displays**

| Characteristic | Definition |
|---|---|
| Name | ≥ 120/200/≥ 200 Hz displays |
| Description | Different display technologies might be used with high frame rate, making it possible to have a higher temporal resolution or use the available frame rate to, for example, show 3D content to each eye. 120 and 200 Hz displays are available for purchase in 2010; higher frequencies systems have been shown by industry. |
| Mass market deployment | By 2012 |
| Sub category | 2D/3D switchable |
| Related technology | Polarized glasses/goggles<br>Shutter glasses/goggles<br>Autostereoscopic displays: Single-user<br>Autostereoscopic displays: Multi-view |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out all actions including maintenance and setup<br>08 Avoid unintentional activation of controls<br>09 Be able to recover from errors<br>10 Have equivalent security and privacy<br>11 Not cause personal risk (e.g. seizure, etc.)<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any accessibility features needed)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- 3D visual effect might not be experienced by parts of the user population.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Handling of glasses/goggles (if needed) might pose a problem for some impaired users.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- User limitation compensation: glasses/goggles ought to provide for ergonomic fit and/or the ability to adapt to individual wearers as users might not be able to readjust the glasses themselves.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | None identified |
| Benefit for all users | - Sharper images (no motion blur/flickering) can be achieved.<br>- Ability to display 3D content for increased viewing experience. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - Increased viewing quality can be achieved in terms of sharper images and avoidance of flickering.<br>- New (3D) content can be offered to customers. |
| Deployment cons | - Potentially, higher energy consumption of displays.<br>- Broadcasting formats and receiver technologies might be incompatible.<br>- 3D viewing might only possible with (additional) polarised/shutter glasses.<br>- Stereovision (eyesight ability) is a prerequisite to perceiving 3D display effects.<br>- Unclear health-risk (headache, nausea, consequences for young children's visual perception) when used as 3D display. |
| Implementation requirements | None identified |
| Harmonization | - Display technology should accept different content formats and may need to handle them automatically. |

**Table 6.13.34: Shutter glasses/goggles**

| Characteristic | Definition |
|---|---|
| Name | Shutter glasses/goggles (Stereoscopic display) |
| Description | The stereoscopic image is produced by showing images for the left and right eye in succession ("alternate image"). Active shutter glasses receive a signal from the display showing these images, thus synchronizing which of the lenses needs to be obscured so that only one eye sees the respective image. |
| Mass market deployment | By 2012 |
| Sub category | 2D/3D switchable |
| Related technology | Polarized glasses/goggles<br>Autostereoscopic displays: Single-user<br>Autostereoscopic displays: Multi-view |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out all actions including maintenance and setup<br>07 Be able to complete actions and tasks within the time allowed<br>08 Avoid unintentional activation of controls<br>11 Not cause personal risk (e.g. seizure, etc.)<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any accessibility features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- 3D visual effect might not be experienced by part of the user population.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Handling of glasses/goggles might pose a problem for some impaired users.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- User limitation compensation: glasses/goggles ought to provide for ergonomic fit and/or the ability to adapt to individual wearers as users might not be able to readjust the glasses themselves.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | None identified |
| Benefit for all users | - The display of 3D content can give a heightened viewing experience. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - One of the cheapest solutions for 3D viewing.<br>- Available in products offering as of 2010. |
| Deployment cons | - Stereovision (eyesight ability) is a prerequisite to perceiving 3D display effects.<br>- Unclear health-risk (headache, nausea, consequences for young children's visual perception). |
| Implementation requirements | - Requires a ≥ 120 Hz TV/projector with a synchronizing signal transmitter for the shutter glasses.<br>- Suitable media content distribution or encoder providing the alternate image sequence is needed, if the display/projector does not contain an image processing engine that provides "on-the-fly" encoding. |
| Harmonization | - Possible health risks are currently not clear, nor are their extent fully understood yet. A framework for these possible risks needs to be investigated. |

**Table 6.13.35: Autostereoscopic displays: Single-User**

| Characteristic | Definition |
|---|---|
| Name | Autostereoscopic displays: Single-User |
| Description | In an autostereoscopic display for single-users, only one user is supported. Often, the display will be coupled with head-/eye tracking systems that can sense the perspective needed to display individual images to the right and left eye. Other techniques used are parallax barriers (precision slits in front of a display so that each eye sees a different pixel set) or lenticular lenses (an array of magnifying lenses in front of a display that allow the showing of two different images viewed from slightly different angles). |
| Mass market deployment | By 2015 |
| Sub category | 2D/3D switchable |
| Related technology | Autostereoscopic displays: Multiview<br>≥ 120/200/ ≥ 200 Hz display<br>See also: sensing technologies |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out actions including maintenance and setup<br>07 Be able to complete actions and tasks within the time allowed<br>08 Avoid unintentional activation of controls<br>09 Be able to recover from errors<br>11 Not cause personal risk (e.g. seizure, etc.)<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any accessibility features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- 3D visual effect might not be experienced by part of the user population.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Handling of glasses/goggles might pose a problem for some impaired users.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- User limitation compensation: in sensing the position of users.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | - In social settings where multiple viewers are common, such as in families, the usage as a single-user autostereoscopic display may be unsuited/unwanted. |
| Benefit for all users | - The display of 3D content can give a heightened viewing experience. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - 3D viewing experience without additional glasses (comfort factor). |
| Deployment cons | - Stereovision (eyesight ability) is a prerequisite to perceiving 3D display effects. |
| Implementation requirements | - ≥ 120 Hz displays are needed.<br>- Displaying of 2D content should achieve acceptable image quality (e.g. as far as distortion is concerned).<br>- A (automatic) fallback to 2D content viewing settings might need to be provided. |
| Harmonization | - Possible health risks are currently not clear. Nor are their extent fully understood yet. A framework for these possible risks needs to be investigated. |

**Table 6.13.36: Autostereoscopic displays: MultiView**

| Characteristic | Definition |
|---|---|
| Name | Autostereoscopic displays: MultiView |
| Description | Autostereoscopic MultiView displays allow multiple users or one user to view visual content in 3D from different perspectives, allowing different images to be shown to each eye creating the autostereoscopic (3D) effect without additional (polarized/shutter glasses). Different technologies are currently being developed. These types of displays will probably be combined with sensor technologies that track the viewers' position. |
| Mass market deployment | By 2015 |
| Sub category | 2D/3D switchable |
| Related technology | Autostereoscopic displays: Single-User<br>≥ 100/200/≥ 200 Hz displays<br>See also: Sensing technologies |
| User requirements | 01 Perceive visual information<br>02 Perceive auditory information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation<br>06 Be able to invoke and carry out actions including maintenance and setup<br>07 Be able to complete actions and tasks within the time allowed<br>08 Avoid unintentional activation of controls<br>09 Be able to recover from errors<br>11 Not cause personal risk (e.g. seizure, etc.)<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any accessibility features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- 3D visual effect might not be experienced by part of the user population.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- User limitation compensation: in sensing the position of users.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | None identified |
| Benefit for all users | - The display of 3D content can give a heightened viewing experience. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - Shared 3D viewing experience without additional glasses (comfort factor). |
| Deployment cons | - Stereovision (eyesight ability) is a prerequisite to perceiving 3D display effects. |
| Implementation requirements | - Currently major reduction in resolution as each of the "view" needs to be displayed by the image generating display, i.e., the physical resolution divided by the number of views supported is the actual achievable resolution of the display.<br>- Even more complex is the production (and distribution) of autostereoscopic MultiView content as it needs to recorded with multiple cameras simultaneously - this is workable for computer-generated content, but resource-intensive for recording of natural content.<br>- ≥120 Hz displays are needed.<br>- 2D content displaying might pose perceived image quality problems (e.g. distorted image). |
| Harmonization | - Possible health risks are currently not clear nor is the extent of the risk fully understood yet. A framework for these possible risks needs to be investigated. |

**Table 6.13.37: Holographic displays**

| Characteristic | Definition |
|---|---|
| Name | Holographic displays |
| Description | Holographic displays project the reconstructed light (inference patterns) from a recorded scene (diffraction of a wavefront encountering an object) so that it appears as if objects are at the same position making the image to appear three-dimensional. Combination with head-tracking/positioning-sensing systems is very likely. |
| Mass market deployment | After 2015 |
| Sub category | 2D/3D switchable |
| Related technology | Direct Volume Display Devices (DVDD)<br>See also: Sensing technologies |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation setup<br>07 Be able to complete actions and tasks within the time allowed<br>08 Avoid unintentional activation of controls<br>09 Be able to recover from errors<br>11 Not cause personal risk (e.g. seizure, etc.)<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any accessibility features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- 3D visual effect might not be experienced by part of the user population.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | None identified |
| Benefit for all users | - The display of 3D content can give a heightened viewing experience. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - New applications/experiences of visual information displays due to the true 3D impression. |
| Deployment cons | - Stereovision (eyesight ability) is a prerequisite to perceiving 3D display effects. |
| Implementation requirements | - There are many issues that remain with holographic displays, e.g.:<br>- Handling/processing enormous amounts of data is required.<br>- Difficult to go beyond monochromatic displays.<br>- It is likely that further improvements in systems will be based upon using simultaneously head-tracking and "Viewing Window" technologies (reducing the overall size of data needed to process for the holographic image generation) for optimization. |
| Harmonization | - None identified |

**Table 6.13.38: Direct Volume Display Devices (DVDD)**

| Characteristic | Definition |
|---|---|
| Name | Direct Volume Display Devices (DVDD) |
| Description | This type of display forms a visual impression in three dimensions (e.g. through rotating light spots called "Voxels") as opposed to "classical" display screens that only have a x-y planar surface and generate 3-dimensional visual impressions through visual effects |
| Mass market deployment | After 2015 |
| Sub category | 2D/3D switchable |
| Related technology | Holographic displays |
| User requirements | 01 Perceive visual information<br>03 Perceive existence and location of actionable components<br>04 Perceive status of controls and indications<br>05 Perceive feedback from an operation setup<br>07 Be able to complete actions and tasks within the time allowed<br>08 Avoid unintentional activation of controls<br>09 Be able to recover from errors<br>11 Not cause personal risk (e.g. seizure, etc.)<br>12 Be able to efficiently operate product<br>13 Understand how to use product (including discovery and activation of any accessibility features needed)<br>14 Understanding the output or displayed material (even after they perceive it accurately)<br>15 Ability to use their assistive technology (AT) to control the ICT |
| Accessibility barriers | - Displayed content might not be accessible for people with visual impairments.<br>- 3D visual effect might not be experienced by part of the user population.<br>- Visually impaired users need to be able to perceive the existence of controls and receive feedback of operations in adequate ways.<br>- Usage and connection of assistive devices is limited or not possible. |
| Solutions related to accessibility barriers | - Multimodal presentation: consider provision of multimodal presentation.<br>- Multimodal control: allow for multimodal control of the device.<br>- Object navigation: allow for navigation between displayed objects.<br>- Selective magnification: allow for the magnification of displayed objects.<br>- Displayed information adjustability: allow for flexible adjustment of the displayed information.<br>- Standardized Assistive Device connection: provision should be made for connecting standardized assistive devices. |
| Cultural issues | None identified |
| Benefit for all users | - The display of 3D content can give a heightened viewing experience. |
| Benefits for older people and people with disabilities | None identified |
| Deployment pros | - New applications/experiences of visual information displays due to the true 3D impression. |
| Deployment cons | - Stereovision (eyesight ability) is a prerequisite to perceiving 3D display effects. |
| Implementation requirements | - Fundamental problem: The number of Voxels required increases as a cubic function with resolution, producing large amounts of data to be processed. |
| Harmonization | None identified |

# Annex A: Alphabetic list of user interaction technologies

**Table A.1: Alphabetic list of user interaction technologies**

| User interaction technology | Sub category | User interaction roadmap | Table |
|---|---|---|---|
| ≥ 120/200/≥ 200 Hz displays | 2D/3D switchable | Visual output technologies | 6.13.33 |
| 2/4/8 k Home cinema projection | Projection | Visual output technologies | 6.13.17 |
| 3D audio/virtual acoustics | Advanced sound experience | Acoustic/audio output technologies | 6.9.17 |
| 3D scanning | Image analysis technologies | Visual Input technologies | 6.8.2 |
| 3-dimensional touch devices | Multi-touch gesture input | Touch-based input technologies | 6.7.10 |
| Active noise reduction | Advanced loudspeakers | Acoustic/audio output technologies | 6.9.5 |
| Adaptive directive microphones | Advanced microphones | Acoustic/audio input technologies | 6.2.4 |
| Advanced display loudspeakers | Advanced loudspeakers | Acoustic/audio output technologies | 6.9.2 |
| Advanced non-linear acoustic echo cancellation (AEC) | Advanced sound experience | Acoustic/audio output technologies | 6.9.15 |
| Advanced speech synthesis | Voice-output technologies | Acoustic/audio output technologies | 6.9.19 |
| Aerosol powered distribution | Smell-based output | Smell-based output technologies | 6.11.2 |
| Aerosol powered distribution | Taste-based output | Taste-based output technologies | 6.12.2 |
| Ambient acoustic landscapes ("sound scapes") | Advanced sound experience | Acoustic/audio output technologies | 6.9.12 |
| Audio-visual speech recognition | Voice-input technologies | Acoustic/audio input technologies | 6.2.14 |
| Auditory UI | Voice-input technologies | Acoustic/audio input technologies | 6.2.10 |
| Autostereoscopic displays: MultiView | 2D/3D switchable | Visual output technologies | 6.13.36 |
| Autostereoscopic displays: Single-User | 2D/3D switchable | Visual output technologies | 6.13.35 |
| Blind source separation | Advanced microphones | Acoustic/audio input technologies | 6.2.6 |
| Body-based exoskeletons | Body-based haptic/tactile | Haptic/tactile output technologies | 6.10.10 |
| Bone-conducting earphones | Advanced sound experience | Acoustic/audio output technologies | 6.9.13 |
| Clark synthesis tactile transducer | Advanced sound experience | Acoustic/audio output technologies | 6.9.10 |
| Colour electronic-paper displays | Direct-view | Visual output technologies | 6.13.5 |
| Communications badge | Advanced microphones | Acoustic/audio input technologies | 6.2.7 |
| Complex full hand model tracking | Image analysis technologies | Kinaesthetic input technologies | 6.3.9 |
| Contact lens displays | Handheld/mobile | Visual output technologies | 6.13.25 |
| Device-mounted inertial sensors | Sensor-based technologies | Kinaesthetic input technologies | 6.3.10 |
| Dielectric elastomers | Finger/hand-based haptic/tactile | Haptic/tactile output technologies | 6.10.3 |
| Direct Volume Display Devices (DVDD) | 2D/3D switchable | Visual output technologies | 6.13.38 |
| Displays in clothes, fashion accessories | Handheld/mobile | Visual output technologies | 6.13.24 |
| Distributed speech recognition | Voice-input technologies | Acoustic/audio input technologies | 6.2.13 |
| Dry electrode physiological monitoring | Mood/activity sensing | Recognition/mood/arousal-based input technologies | 6.5.14 |
| Dual-touch gesture recognition | Multi-touch gesture input | Touch-based input technologies | 6.7.4 |
| Multi-touch gesture recognition with various input devices | Multi-touch gesture input | Touch-based input technologies | 6.7.6 |
| Electronic olfactometers | Smell-based input | Smell-based input technologies | 6.6.2 |
| Electronic-paper displays (greyscale) | Direct-view | Visual output technologies | 6.13.2 |
| Electrostatic actuation | Finger/hand-based haptic/tactile | Haptic/tactile output technologies | 6.10.4 |
| Electrowetting displays | Direct-view | Visual output technologies | 6.13.8 |
| Environment-scale proximity | Proximity sensing | Presence/location/proximity-based input technologies | 6.4.7 |
| Eye contact (integrated) cameras | Camera technologies | Visual Input technologies | 6.8.6 |
| Eye tracking | Image analysis technologies | Kinaesthetic input technologies | 6.3.6 |
| Eye-lid monitoring | Mood/activity sensing | Recognition/mood/arousal-based input technologies | 6.5.12 |
| Fabric sound system | Advanced loudspeakers | Acoustic/audio output technologies | 6.9.4 |
| Facial recognition | Remote interaction person recognition | Recognition/mood/arousal-based input technologies | 6.5.7 |

| User interaction technology | Sub category | User interaction roadmap | Table |
|---|---|---|---|
| Fan powered distribution | Taste-based output | Taste-based output technologies | 6.12.6 |
| Fan-powered distribution | Smell-based output | Smell-based output technologies | 6.11.5 |
| Flexible electronic-paper displays | Direct-view | Visual output technologies | 6.13.7 |
| Gesture recognition | Image analysis technologies | Kinaesthetic input technologies | 6.3.3 |
| Hand model tracking | Image analysis technologies | Kinaesthetic input technologies | 6.3.2 |
| Hand shape recognition | Direct interaction person recognition | Recognition/mood/arousal-based input technologies | 6.5.3 |
| Hand vein recognition | Direct interaction person recognition | Recognition/mood/arousal-based input technologies | 6.5.5 |
| Hand-based exoskeletons | Finger/hand-based haptic/tactile | Haptic/tactile output technologies | 6.10.7 |
| Handheld-based AR | Visual AR | Visual output technologies | 6.13.26 |
| Head mounted displays | Projection | Visual output technologies | 6.13.15 |
| Head tracking | Image analysis technologies | Kinaesthetic input technologies | 6.3.5 |
| Head-up displays (HUD) | Projection | Visual output technologies | 6.13.12 |
| Heat powered distribution | Taste-based output | Taste-based output technologies | 6.12.3 |
| Heat-powered distribution | Smell-based output | Smell-based output technologies | 6.11.6 |
| Holographic displays | 2D/3D switchable | Visual output technologies | 6.13.37 |
| Inkjet-like distribution | Smell-based output | Smell-based output technologies | 6.11.3 |
| Inkjet-like distribution | Taste-based output | Taste-based output technologies | 6.12.4 |
| Integrated gas-sensing devices | Smell-based input | Smell-based input technologies | 6.6.3 |
| Intelligent (MEMS) microphones | Advanced microphones | Acoustic/audio input technologies | 6.2.8 |
| Intelligent word spotting | Voice-input technologies | Acoustic/audio input technologies | 6.2.12 |
| Interactive floors | Projection | Visual output technologies | 6.13.14 |
| Iris recognition | Direct interaction person recognition | Recognition/mood/arousal-based input technologies | 6.5.2 |
| Keystroke dynamics recognition | Direct interaction person recognition | Recognition/mood/arousal-based input technologies | 6.5.4 |
| Large displays ≥ 254 cm (≥ 100 inches) | Direct-view | Visual output technologies | 6.13.9 |
| Liquid-based distribution | Taste-based output | Taste-based output technologies | 6.12.7 |
| Local 3-D scene analysis | Sensor-based technologies | Kinaesthetic input technologies | 6.3.11 |
| Locally-sensed location | Location sensing | Presence/location/proximity-based input technologies | 6.4.4 |
| Low light cameras | Camera technologies | Visual Input technologies | 6.8.7 |
| Mechanical pump distribution | Smell-based output | Smell-based output technologies | 6.11.4 |
| Mechanical pump distribution | Taste-based output | Taste-based output technologies | 6.12.5 |
| Mini-projectors | Projection | Visual output technologies | 6.13.11 |
| Mobile HD video displays | Handheld/mobile | Visual output technologies | 6.13.21 |
| Multi touch with hover recognition | Multi-touch gesture input | Touch-based input technologies | 6.7.8 |
| Multi-camera eye sensing | Mood/activity sensing | Recognition/mood/arousal-based input technologies | 6.5.13 |
| Multi-channel audio | Advanced sound experience | Acoustic/audio output technologies | 6.9.11 |
| Multi-touch movement recognition | Multi-touch gesture input | Touch-based input technologies | 6.7.7 |
| Near screen gesture recognition | Image analysis technologies | Kinaesthetic input technologies | 6.3.7 |
| NFC tag sensing | Object-recognition based user interaction | Recognition/mood/arousal-based input technologies | 6.5.11 |
| Night vision (goggles) | Handheld/mobile | Visual output technologies | 6.13.23 |
| Non-linear distortion reduction | Advanced loudspeakers | Acoustic/audio output technologies | 6.9.7 |
| Object adaptive projection | Projection | Visual output technologies | 6.13.19 |
| OLED displays | Direct-view | Visual output technologies | 6.13.3 |
| Optical microphones | Advanced microphones | Acoustic/audio input technologies | 6.2.2 |
| Pen-based capacitive touch recognition | Pen-based gesture input | Touch-based input technologies | 6.7.11 |
| Pen-based capacitive touch/hover recognition | Pen-based gesture input | Touch-based input technologies | 6.7.12 |
| Personal mobile loudspeakers | Advanced loudspeakers | Acoustic/audio output technologies | 6.9.6 |
| Personal mobile microphones | Advanced microphones | Acoustic/audio input technologies | 6.2.5 |
| Person-scale proximity | Proximity sensing | Presence/location/proximity-based input technologies | 6.4.6 |
| Piezo-electric actuation | Finger/hand-based haptic/tactile | Haptic/tactile output technologies | 6.10.2 |
| PIR sensing | Presence sensing | Presence/location/proximity-based input technologies | 6.4.2 |

| User interaction technology | Sub category | User interaction roadmap | Table |
|---|---|---|---|
| Pneumatic systems | Finger/hand-based haptic/tactile | Haptic/tactile output technologies | 6.10.5 |
| Polarized glasses/goggles (Stereoscopic display) | 2D/3D switchable | Visual output technologies | 6.13.32 |
| Polymer-based shape displays | Finger/hand-based haptic/tactile | Haptic/tactile output technologies | 6.10.8 |
| Pressure sensitive touch recognition | Multi-touch gesture input | Touch-based input technologies | 6.7.9 |
| Projected keyboards/controls | Image analysis technologies | Kinaesthetic input technologies | 6.3.4 |
| Remote 3-D scene analysis | Sensor-based technologies | Kinaesthetic input technologies | 6.3.12 |
| Remotely-sensed location | Location sensing | Presence/location/proximity-based input technologies | 6.4.5 |
| Resistive multi-touch recognition | Multi-touch gesture input | Touch-based input technologies | 6.7.5 |
| Resonance speakers | Advanced loudspeakers | Acoustic/audio output technologies | 6.9.3 |
| Retinal blood vessel recognition | Direct interaction person recognition | Recognition/mood/arousal-based input technologies | 6.5.6 |
| Retinal projectors | Projection | Visual output technologies | 6.13.18 |
| Reverberation reduction | Advanced sound experience | Acoustic/audio output technologies | 6.9.14 |
| RF device sensing | Presence sensing | Presence/location/proximity-based input technologies | 6.4.3 |
| RFID tag sensing | Object-recognition based user interaction | Recognition/mood/arousal-based input technologies | 6.5.10 |
| Seated body movement sensing | Sensor-based technologies | Kinaesthetic input technologies | 6.3.13 |
| See-through contact lenses AR | Visual AR | Visual output technologies | 6.13.30 |
| Shutter glasses/goggles | 2D/3D switchable | Visual output technologies | 6.13.34 |
| Sign-language recognition | Image analysis technologies | Kinaesthetic input technologies | 6.3.8 |
| Silicon microphones | Advanced microphones | Acoustic/audio input technologies | 6.2.3 |
| Single touch with hover recognition | Single touch input | Touch-based input technologies | 6.7.2 |
| Smart floor gait analysis | Remote interaction person recognition | Recognition/mood/arousal-based input technologies | 6.5.9 |
| Smart microphone arrays | Advanced microphones | Acoustic/audio input technologies | 6.2.9 |
| Sound beam | Advanced loudspeakers | Acoustic/audio output technologies | 6.9.8 |
| Sound-absorption materials (e.g. textiles) | Acoustic environments | Acoustic/audio output technologies | 6.9.18 |
| Spatial AR | Visual AR | Visual output technologies | 6.13.29 |
| Spatially immersive displays | Projection | Visual output technologies | 6.13.13 |
| Speaker recognition | Remote interaction person recognition | Recognition/mood/arousal-based input technologies | 6.5.8 |
| Speech recognition | Voice-input technologies | Acoustic/audio input technologies | 6.2.11 |
| Stereoscopic cameras | Camera technologies | Visual Input technologies | 6.8.3 |
| Stereoscopic micro HD cameras | Camera technologies | Visual Input technologies | 6.8.4 |
| Super-Hi Vision | Direct-view | Visual output technologies | 6.13.10 |
| Tabletops/multi-touch displays | Direct-view | Visual output technologies | 6.13.6 |
| Touch screen with haptically perceivable actionable areas | Single touch input | Touch-based input technologies | 6.7.3 |
| Ultrasonic transducers | Finger/hand-based haptic/tactile | Haptic/tactile output technologies | 6.10.6 |
| (Video-) Wristwatch displays (RSVP) | Handheld/mobile | Visual output technologies | 6.13.22 |
| Wallpaper projection | Projection | Visual output technologies | 6.13.16 |
| Wave field synthesis | Advanced sound experience | Acoustic/audio output technologies | 6.9.16 |
| Wearable cameras | Camera technologies | Visual Input technologies | 6.8.5 |
| Wearable immersive AR | Visual AR | Visual output technologies | 6.13.27 |
| Wearable see-through AR | Visual AR | Visual output technologies | 6.13.28 |
| Wearable tactile displays | Body-based haptic/tactile | Haptic/tactile output technologies | 6.10.9 |
| Wide-band speech extender | Advanced sound experience | Acoustic/audio output technologies | 6.9.9 |
| Wide-colour gamut (WCG) | Direct-view | Visual output technologies | 6.13.4 |

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