Mediate
Patient Friendly Medical Intervention

DELIVERABLE 6.2.2

State of the art regarding available UI concepts

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Deliverable review procedure:

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- **1 week before due date**: co-reviewer provides input to deliverable owner
- **Due date:** deliverable owner sends the final version of the deliverable to PM and co-reviewer

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1. Aim of the activity

This report first introduces several general concepts related to UI, specially focused on Natural User Interaction methods. Then, it presents and state of the art on general purpose interaction methods and devices, highlighting their strengths and weaknesses, according to natural interaction and operating room side table context criterion, as well as their accuracy and development maturity. The most remarkable practical examples of each technology, including both commercial and research prototypes, are presented. The report ends with some conclusions.

The core activities within this part are based on a literature search about the UI. The study has been conducted first in general in order to present the general overview about existing UI concepts. For each of the technology a secondary study about the existing applications in medicine was conducted.

The aim of the deliverable is to provide the technological background to stimulate the further discussion inside task 6.2 about the introduction of novel UI along the IGIT workflow.

2. User Interfaces: an introduction

The medical world requires easy and fast sharing of information. An analysis of the User Interface (UI) concepts is required in order to understand which of them could meet the medical needs.

Since the initial computer systems, where interaction was limited to properly setting the input data and operations to perform and waiting the output results, many advances have been achieved in the way users communicate with computer systems. Nowadays, the most conventional and extended computer system interaction devices include a screen, a keyboard and a mouse. And most of the O.S. provide a graphical user interface based in the use of windows to access to information and perform operations. Nevertheless, a special effort is being put in the research of new user interfaces to improve usability, simplicity and fulfil the restrictions of specific environments. The current trend is to use natural user interfaces. This concept is related to many terms which are recent and have been presented by different authors. Their meaning is usually uniform among authors, but in some cases there are discrepancies. Therefore, the most important terms related to natural human-computer interaction are defined next.

The study, planning and design of the interaction between people and computers is defined as Human-Computer interaction (HCI). The Interaction between users and computers by the use of UI, which includes both software and hardware; for example, characters or objects displayed by software on a personal computer's monitor, input received from users via hardware peripherals such as keyboards and mice, etc..

As stated above, UI is a combination of hardware and software. The hardware is used to provide the input to the system and obtain the output, through a software layer. This software layer usually exposes a graphic output through some kind of display, providing a visual feedback for interaction. The first graphic outputs where command and text based but nowadays they have been replaced by the Graphical User Interface (GUI), which includes all the information and actions available to a user through graphical icons and visual indicators. Actions are usually performed through direct manipulation of the graphical elements. The replacement of text and command based interfaces by GUI was a step forward towards interaction naturalness.

Natural user interfaces (NUI), is the common terms used by designers and developers of computer interfaces to refer to a user interface that is effectively invisible, or becomes invisible with successive learned interactions, to its users[1]. Most computer interfaces use artificial control devices whose operation has to be learned. In this case the goal is to make the user feel like a natural interaction. These types of interfaces require so few learning that user feels to be instantly and continuously successful. Form the technology point of view all these devices allow the users to carry out relatively

[1] http://en.wikipedia.org/wiki/Natural_user_interface

natural motions, movements or gestures. The conventional approaches use hand gestures and touch, speech and eye gaze to interact with the underlying system in a way that tries to emulate common everyday life interaction situations. For some further discussion on NUI, the reader is referred to (NUI, 2009).

Tangible User Interfaces (TUI), introduced by Ishii and Ullmer (Hiroshi Ishii, n d) are graphical interfaces which augment the real physical world by adding digital information to everyday use objects and physical environments. The TUI input events, thus, consists of the manipulation of daily objects with the hands and in the same way as they are used in their usual contexts. The computer system processes the input events, providing the corresponding answer. It has been argued that TUIs provide better global view of state of the system than GUI, discovering relations among objects and inside the application in use. Moreover, TUIs promote concept communication among users, because they are easily illustrated by means of the physical interaction objects. The main benefit of TUI over traditional GUI, is there is an immediate haptic passive response while manipulating a physical object. Without the need to wait for a digital synthetic haptic response, users can accomplish their actions.

Organic User Interfaces (OUI) are User interfaces with non-planar displays that may actively or passively change shape via analog physical inputs[2]. This kind of UI lie in three principles: input equals output (i.e. the display is the input device), function equals form (i.e. the display has the most suitable shape for its function) and form follows flow (i.e. the shape of the display can change).

Ubiquity is an interesting property to consider in NUI. The idea behind this concept is that the computer system is available to interact with it everywhere but without being physically perceived, because it is blended into the environment (Weiser, 1993; 1999) .

Interaction is direct when the object is manipulated acting directly on it (Ghazali & Dix, 2005). Each level of mediating tool required for the object manipulation adds an abstraction level and makes the interaction more indirect. Direct interaction is usually associated to NUI, because the relationship between input and output is immediate and because it is the most common in the everyday life (e.g.: picking a mug from its handle to take it). According to (Ha, Inkpen, Whalen, & Mandryk, n d), these are some differences between direct and indirect interaction devices.

Direct input devices promote a fluid and natural language, since this is the way in which ordinary objects are usually manipulated. They support group improving understanding of the intention and actions of the user manipulating the object by the rest of the group. Also, anticipating the result to an action is immediate. On the negative side, these kinds of devices induce physical tiredness on the user. Direct interaction limits the possibility to reach an object by the device's constraints. Commonplace gestures can be distracting. The input device can produce occlusions on the display. Users can collide physically in the workspace, when trying to access or

[2] http://www.organicui.org/

manipulate it simultaneously. Finally, direct input devices can be seen as intrusive in the territory of another user.

Indirect input devices on the other hand permit an easy access to distant objects. The effort required to use them is low, compared to the effects produced on the objects. Occlusion in the workspace is limited or even discarded. The drawbacks are the limitation of the gestures used, the interaction is less intuitive and the user needs training, there is a loss of spontaneous collaboration, multiple representations of the same thing could also produce distraction and confusion.

Accessibility is also another term involved in NUI and it is the ability of a user interface (or device) to be available to be used from many people as possible.In other words is the attitude to be accessed providing benefits to some system or entity. Accessibility is often used to focus on people with disabilities or special needs and their right of access to entities, often through use of assistive technology.

Usability, or user-friendly specifically for UI, is the ease of use and learn ability of a human-made object. The object of use can be a software application, website, book, tool, machine, process, or anything a human interacts with. Usability includes methods of measuring usability and the study of the principles behind an object's perceived efficiency or elegance.

2.1 Medical UI

Not all the traditional user interfaces are suitable to be used in the medical field. For example, keyboard and mouse are not suitable for surgical environments because of different reasons:

- are not appropriate for 3D interaction;
- cannot be placed in reach;
- are obstructive for the physician ;
- cannot be sterilised.

Especially for intra-operative surgery assistance some characteristics must be considered:

- Sterilization of the operating room (the entire environment and all the equipment).
- No discharged air of computers or projectors.
- Possibility of electromagnetic interference (tracking systems vs. imaging devices).
- As few cables as possible and handy devices in order not to constrain (stress) the physician.
- Ergonomics.

As was explained by (Nielsen, 2007) in the paper “Medical Usability: How to Kill Patients Through Bad Design” the usability design of UIs and more in general of medical devices is a crucial aspect that has to be considered in any medical development .

A recently published international standard (ISO/IEC 62366: Application of Usability Engineering to Medical Devices) requires manufacturers of medical devices to follow a systematic usability process and a user centric design.

The documents is particular important because is setting the direction for the usability of medical user interfaces. In particular it describes a Usability Engineering Process which is an iterative process composed of 9 stages:

1. Specify the application of the medical device.
2. Identify the device’s frequently used functions.
3. Identify hazards and hazardous situations related to usability.
4. Identify the device's primary operating functions.
5. Develop the usability specification.
6. Prepare the usability validation plan.
7. Design and implement the user interface.
8. Verify the user interface design.
9. Validate the usability of the medical device.

3. Review of the advanced and innovative concepts in NUI and available technologies

In this section some of the most extended, yet innovative NUI are introduced and reviewed according to several criterions like accessibility, usability, accuracy and sterility. But first, each of these terms is presented.

Accessibility is also another term involved in NUI and it is concerned about the process of creating products (devices, environments, systems, and processes) which are usable by people with the widest possible range of abilities, operating within the widest possible range of situations (environments, conditions, and circumstances), as is commercially practical(Vanderheiden & Tobias, n d).

Is the "ability to access" and possible benefit of some system or entity. Accessibility is often used to focus on people with disabilities or special needs and their right of access to entities, often through use of assistive technology.

Usability refers to how easy users can learn and use a UI to achieve their goals and how satisfied they are with that human-computer interaction process.

Usability includes methods of measuring usability and the study of the principles behind an object's perceived efficiency or elegance.

Usability differs from user satisfaction insofar as the former also embraces usefulness.

3.1 Speech recognition

Speech-based interactions allow users to communicate with computers or computer-related devices without the use of a keyboard, mouse, buttons, or any other physical interaction device. By leveraging a skill that is mastered early in life, speech-based interactions have the potential to be more natural than interactions using other technologies such as the keyboard. Based on the input and output channels being employed, speech interactions can be categorized into three groups: spoken dialogue systems, speech output systems and speech recognition systems.

Spoken dialogue systems include applications that utilize speech for both input and output, such as telephony systems and speech-based environment control systems with voice feedback. Speech output systems include applications that only utilize speech for output while leveraging other technologies, such as the keyboard and mouse, for input. Screen access software, which is often used by individuals with visual impairments, is an example of speech output. Speech recognition systems include applications that utilize speech for input and other modalities for output, such as speech-based cursor control in a GUI and speech-based dictation systems. This introduction, extracted from (Feng & Sears, 2009), presents a clear definition and classification of these UI. It is also remarkable that speech can be both an input (speech recognition) and output (speech synthesis or Text To Speech, TTS) interface. The conventional

approach is to perform a translation between voice and text both for speech recognition and synthesis.
Another classification distinguishes among different input vocabulary sizes supported into small and large vocabulary solutions. In small vocabulary solutions the interaction is based on a reduced set of predefined simple commands. In some systems there is a direct match between the acoustic signals with models associated with each of the currently available commands, while other systems allow users to customize these models. The set of commands is specifically defined for a narrow and fixed context. Voice dialing systems are an example of this category. On the other hand, large vocabulary, also denoted as dictation systems, because of their main purpuse, have to deal with a huge number of words (>20000) and their main purpose is not to control some system, but to convert speech into comprehensive text. The accuracy of these systems is lower than small vocabulary solutions, even after a user specific training, which is mandatory to adapt the system to the user. Many different procedures have been tried to overcome the accuracy issues in the last decade, but it is still one of the main problems. For both kinds of systems, their integration into a multimodal UI can improve the accuracy, by putting words into a specific context, and also by reducing the size of the speech interaction language required.
Speech seems to be well suited for multimodal UI, where the speech is used to indicate complex actions while the other UI, like hand gestures, eye-gaze, multitouch, etc.are used to set the context of application (deictic gestures).
As with other UI, the target user should take part in the design from the very begining, first because the success of a speech application depends on undestanding the vocabulary, speech patterns, and interaction preferences of the target user, and second because different user communities may adopt different interaction strategies when completing the same tasks.
For speech synthesis applications, the dynamic nature of voice should be taken into account. When using to present a list of possible interactions, the dialogs may let the caller repeat or ask the application to repeat, but the speech cannot be frozen. It is also recommended to a maximum number of five menu items unless the barge-in feature is enabled. The effects of system response time are still an area of research and study even if general behaviours are now well understood. For a system speech response to feel natural some kind of delay time must be present between the user input and the system’s speech output.
The only device that a user may need to wear is a microphone, and only for certain environments. This fact combined with a proper design following the ideas previously presented produces a natural user interface. This UI only needs the user to be able to speak/listen and therefore it is accesible for most of people and environments. It can also be suitable for environments with high hygienic restrictions, since there is no contact.

On the disadvantages, the main problems are distinguishing between intended and unintended interaction, they lack of robustness for noisy environments, and the main nature of this UI makes it have lower accuracy than others. Some of these problems can be partially addressed by user wearable microphones and a push-to-talk interaction where some action (button) or voice command indicates to the system that the user is going to start interaction. But the accuracy issue is related both to technical issues and the inherent anbiguity and complexity of human language.
The user is referred to (Jurafsky & Martin, 2008) for a deep understanding of speech recognition techniques. There are several speech recognition software packages available. Refer to (Nguyen, 2009) for a list of current software and API available. Finally, some current implementations of speech UI in clinics are presented in part III of (Neustein, 2010).

3.2 Voice Control

Voice based user interfaces provide human interaction with computers through a voice/speech platform in order to initiate an automated service or process. There are already several speech recognition software packages available.
In the specific of the medical field, speech recognition technology is a recent development in minimally invasive surgery. Voice-activated control system for minimally invasive surgery, are being introduced into clinical practice. Some reports have objectively evaluated the utility of the voice-activated control system (Salama & Schwaitzberg, 2005). They report that voice-activated control systems improve communication with and efficiency of OR staff. Surgeons are afforded the most timely equipment adjustment possible while circulating nurses can concentrate on patient care instead of equipment adjustment during the course of the surgery.
SidneHD device control (by Stryker) is platform designed to network the OR, integrating surgical devices, which can be, controlled by simple voice commands. Many pieces of surgical equipment are outside the range of sterility for the surgeon and must be manipulated by a surgical staff while SidneHD enables all needed equipment to be directly under the surgeon's control. Staff has the freedom to use a centralized touch panel, a hand-held tablet or voice recognition to control a wide range of surgical equipment (such as tables, lights, video cameras).

Figure 1: SIDNE Voice activation sysytem (Courtesy of Stryker)

(Luketich et al., 2002) assess the impact of this type of systems on operating room efficiency and user satisfaction concluding that physician and nurse acceptance of it was very high because of the smoother interruption-free environment.

3.3 Eyegaze tracking

There is some naming confusion between two different kinds of systems denoted as eye tracking. On one hand, some systems perform head tracking with optional eye blink detection, but they are not able to recognize where the user is looking at. The head position and orientation is used instead. On the other hand, there are systems which are able to recognize the eye gaze position accurately and in real time, and they can also identify eye blinks. The techniques, advantages and restrictions of these two kinds of systems are very different. This section is devoted only to the latter. There are two main kind of system setups: those which require the user to wear some kind of device (wearing glasses, intraocular devices, helmets, ...) which are intrusive, and those which do not, so the user can seamlessly interact with the system. The main reason to make the user wear a device is to improve the accuracy and robustness of the recognition. This section focuses on the second kind of system, which lets the user interact seamlessly with the system. Most of this commercial gaze-tracking systems measure point-of-regard by the “corneal-reflection/pupil-centre” method (also called bright/dark pupil effect). They require an infrared camera, and an infrared light. The infrared light is directed to the eyes, so the light enters de retina and a large proportion of it is reflected back, making the pupil appear as a bright, well defined disc. (i.e.: bright pupil effect). The corneal reflection is also generated by the infrared light, appearing as a small, but sharp, glint. Once the centre of the pupil and the location of the corneal reflection have been identified, the vector between them is measured, and, with further trigonometric calculations, point-of-regard can be found. A calibration is usually required to adapt the process to each person’s eye movements. The calibration works by displaying a dot on the screen, and if the eye fixes for longer that a certain threshold time and with a certain area, the system records that pupil-centre/corneal-reflection relationship as corresponding to a specific x,y coordinate on the screen. This is repeated over a 9 to 13 point grid-pattern to improve the accuracy. The raw eye tracking information, i.e., the position where each eye is looking at and if it is open o close, is usually pre-processed in order to be robust for interaction. Eye gaze and blinking are usually the more abstract and robust interaction units used instead. Eye gaze refers to focusing to certain point for certain time, and blinking refers to an intentional eye closing followed by reopening again after a minimum threshold time (to distinguish it from an unintentional eye blinking action). Another abstraction level includes Visual Attention Maps, which represent the amount of time spent looking at each location, and it is visualized using heatmaps.

Recently a thesis report has been presented on eye gaze tracking for HCI (Drewes, 2010). Next, a summary of its contents is presented.

Based on the fact that eyes are used for human to human communication, the next conclusions can translated into the HCI field:

1. The eyes can be used both as an input and output interface. Looking at somebody while talking focuses the speech target to him, for example.
2. For natural communication with computers the computer needs to know our gaze direction. It should be the natural way to indicate the context/target of an action request to the computer.
3. Analysing the eye gaze reveals information about the person’s mood intention, and life experience, which can be used to enrich the interaction with computers.

There are many benefits of an eye-gaze interface. The ease of use, because of the naturalness and low strain for the user. The interaction speed-up, since eyes are quick and especially in multimodal interfaces, setting the interaction target. It does not suffer from wear effects, since there is not direct contact. In the same way it is suitable for environments with high hygienic demands, like an operating room for surgery. Remote control of the system is possible, although the current commercial systems impose strong restrictions on the mobility of the user around the system. Safer interaction, e.g. a mobile phone could require eye contact for an outgoing call, to avoid accidental calls. User activity information, e.g. distinguish activities like reading or detect physical or emotional conditions of the user.

On the drawbacks, the eyes perform unconscious moments and this might disturb their use as computer input. There is also a conflict between the use of eyes as input or output. For the eye-gaze interface it is difficult to decide whether the gaze is on an object just for inspection of for invoking an action. Fatigue can also affect eye muscles. Other interfaces can produce repetitive strain injury (RSI). Eyes constantly move, even while sleeping, so there should not be any problem, but it is still an issue to be concerned about.

Since 2000 there is a biannual international conference on eye tracking called ETRA (Eye Tracking Research & Application). And since 2005, the COGAIN (Communication by Gaze Interaction) initiative, supported by the European Commission, also gathers information about eye tracking.

For a list of commercially available systems the user is referred to (“Cogain Wiki,” n d).

This web page also includes a list of open source API and related software. Nevertheless, the most known companies are Tobii and Eye Tech Digital Systems.

In order to choose the most suitable system for a specific task, the main aspects to be considered are:

- Accuracy.
- Time resolution and latency.
- Robustness.
- Low-level filtering.
- API and data visualization.

There are still many challenges to be solved. Some are related to the cameras used, that is, the image resolution, outdoor infrared light, shadows, etc. Others are related to the physical characteristics, like the low accuracy, need for calibration, and the conflicts of using the eyes for both input and output, known as the “Midas Touch” problem. But perhaps the biggest challenge is to use eye tracking for context awareness, to combine it with other UI.

3.4 Gestures recognition based interfaces

In most cases hand postures and gestures are considered identical, but they are not. A hand posture is a static hand pose, while a gesture involves some kind of motion, like a trajectory or poses change, in time. A hand gestures can therefore be defined as a sequence of hand postures, connected by continuous motions in a short time span.

The meaning of a hand gesture depends on these information sources:

- Spatial information (where).
- Pathic information (the path it takes).

Symbolic information (the sign it makes).Gestures can be categorized using the next list where as the list advances, their association with speech declines, language properties increase, spontaneity decreases, and social regulations increases:

- Gesticulation: spontaneous movement of hands and arms, accompanying speech. Constitute around 90% of human gestures.
- Language-like gestures: Gesticulation used into the speech to replace a particular spoken word or phrase.
- Pantomimes: Gestures depicting objects or actions, with or without accompanying speech.
- Emblems: Familiar signs such as “V for victory”, some culture-specific.

- Sign Languages: Well defined linguistic systems. These carry the most semantic meaning and are more systematic, thereby being easier to model in a virtual environment.

Hand gesture recognition techniques can be categorized into device based and computer vision based. The former require the user to wear some kind of device using sensors to determine the hand posture and gestures. The latter rely on the use of some kind of optical sensor, usually not requiring any device on the user. But in some cases markers are put on the user in order to increase accuracy and robustness.

The most natural gesture based user interface is the bare hand gesture interface, because it does not require wearing any kind of device. This section focuses on bare hand gesture based user interfaces. For a review on bare hand gesture recognition techniques, the reader is referred to (Mitra & Acharya, 2007).

The usage of bare hand UI provides these advantages:

- No need of physical contact with any device. Therefore it is suitable for environments with sterility restrictions.
- Significant reduction in space required by traditional input devices.
- High durability due to a reduction in the number of mechanical parts, and since without physical contact there is no wear on the system.
- Simultaneous multiuser interaction is feasible.
- But on the other hand, there are several challenges and drawbacks:
- Tiredness in the user, if it is forced to maintain his arms in a not-comfortable position for an extended period of time.
- Limited accuracy and robustness unless in restricted conditions. It depends on the kind of gesture used (e.g.: free 3D trajectory gestures, or complex gestures involving many postures with occlusions can be very challenging), distance to the recognition system, and the limitations of the recognition process. Tiredness can also be a source of reduced accuracy. And the robustness of optical systems can be affected by disturbances in lighting.
- Distinguishing when a gesture starts and ends is very difficult just like in speech interfaces.

Bare hand gesture UI’s are better suited for these scenarios:

- Limited space on the device.
- Hard to reach places.
- Sterile environments.

Human gestures related to several part of the body (i.e. face or hands) can be interpreted using mathematical algorithms and translated into a natural user interface. There are various types of gestures which can be identified and processed by computers:

1. *Sign language recognition.*
2. *Directional indication through pointing*.
3. *Control through facial gestures (for example eye tracking to control a display*.
4. *Immersive game technology.*
5. *Affective computing (to identify emotional expression through computer systems). Remote control*.

3.4.2 Input devices suitable to be used for gesture recognition

There are basically four possibilities to track person's movements determining in order to recognize gestures:

1. ***Optical Systems.***
   a) *Depth-aware cameras.* They are based on depth map used to approximate a 3d representation of what is being seen. These can be suitable for detection of hand gestures due to their short range capabilities.
   b) *Stereo cameras.* If the relations between two cameras are known, then it is possible to triangulate in order to obtain the 3d representation of the space.
   c) *Single camera.* A normal camera can be used for gesture recognition where the resources/environment would not be convenient for other forms of image-based recognition. Although not necessarily as effective as stereo or depth aware cameras, using a single camera allows a greater possibility of accessibility to a wider audience.
2. ***Controller-based gestures.***
   In this case the controllers act as an extension of the body: when gestures are performed, motion are conveniently captured by the software (for example mouse, Wii remote controller, etc.).

3.4.3 Medical Applications of gesture recognition

Some studies (Feied et al., 2006; J. P. Wachs et al., 2008) have shown that gesture recognition techniques can support medical imaging manipulation or other medical tasks inside the operating theatre. This concept shows some benefits (for example allows doctors' hands to remain sterile, supporting their focus of attention, and providing fast response times). It is reasonable to think that the future will present new application of gesture recognition in the medical field (for example for electronic health record management).

Figure 2: on the left, one example of applied medical research in the field of gesture recognition for browding of radiology images (*Gestix*, (J. P. Wachs et al., 2008)**). It is an application based on a real-time hand-tracking recognition technique using color and motion fusion. On the right, an application of gesture recognition expected in the near future.**

3.5 Multitouch interfaces

Multi-touch (or multitouch) denotes a set of interaction techniques which allow computer users to control graphical applications with several fingers. Multitouch UI could be interpreted as a particular case of hand gesture UI, but due to some significant differences in their advantages and disadvantages and the recent interest and developments it is covered in a separate section.

Multi-touch consists of a touch screen (screen, table, wall, etc.) or touchpad, as well as software that recognizes multiple simultaneous touch points, as opposed to the standard touchscreen (e.g. computer touchpad, ATM), which recognizes only one touch point. This effect is achieved through a variety of means, including but not limited to: heat, finger pressure, high capture rate cameras, infrared light, optic capture, tuned electromagnetic induction, ultrasonic receivers, transducer microphones, laser range finders, and shadow capture (Pennock & Tabrizi, 2008).

For an incomplete chronology of multitouch techniques, readers are referred to (Buxton, 2011). And for some advices on interface design the user is referred to (Saffer, 2008).

Many technologies have been used in order to obtain multitouch devices. Next, the most common are presented:

- Optical Multitouch Surfaces:

Optical multitouch surfaces consist of an optical sensor, usually a camera, a light source, usually infrared and a visual feedback, usually in the form of a video projector but also in the form of an LCD screen. The devices using these technologies are usually cheap and scalable to big size screens. Additionally, there is no need for hard pressure for recognition to perform correctly (FTIR is an exception). Unfortunately, in many cases, the recognition resolution does not increase linearly to the size of the screen, since it depends on the camera resolution. And increasing the camera image resolution can have a huge impact on the touch recognition framerate. These devices usually require using a video projector, which increases the complexity and size of the setup and imposes restrictions on the environmental lighting. Lighting constraints are also imposed by the use of optical sensors. Therefore, they are usually limited to indoor use. The most conventional approach is called Frustrated Total Internal Reflection (FTIR) (Han, 2005), but there are many others like Diffused Illumination (DI), Diffused Surface Illumination (DSI), Laser Light Plane (LLP), etc. The Natural User Interface (NUI) group has published a document describing the majority of them (NUI, 2009). The Microsoft Surface, including the soon to be released new 2.0 version, is a tabletop composed a computer, an API, and a mulitoutch surface that makes use of optical multitouch surfaces.

- Capacitive Multitouch Surfaces:

The main component used in this kind of devices is the capacitor. A simple parallel plate capacitor consists of two metal plates of about the same size, facing each other without touching. One of the plates is usually connected to ground while the other is attached toa voltage source. When applying a voltage to those plates, the resulting current charges the capacitor. The amount of charge it can hold depends on the voltage applied and onteh capacitance of the capacitor. By measuring the capacitance of a capacitor, one can detect:

- A change in plate size or overlapping area. This can be caused by sliding one of the plates.
- Change in distance between the plates. This can be caused by movement of one of the plates.
- A change in the dielectric value of the medium. This can be caused by an object with a different dielectric constant being placed between the plates.

Taking advantage of the capacitor's characteristics mentioned above, two kind of multitouch techniques have been invented. These techniques are based on the use of low intensity electric fields, and they are called the human shunt and the human transmitter. Later, a technique called Projected Capacitive was also discovered.

The most representative multitouch surface using these techniques is called Diamond Touch and it is based on the human transmitter principle. It was developed by Mitsubishi Electric Research Laboratories (MERL). The most remarkable feature of this surface is that it can identify each touch with the user which did it. On the contrary, users must wear or touch a device to create the electric field, reducing the naturalness of interaction.

This technology supports zero pressure touch sensing, and provides a very smooth interaction, but only conductive objects can be recognize, e.g.: if using gloves, the system would not be able to recognize any touch. It can be affected by electromagnetic interferences. It is expensive and it is difficult to port it to large scale displays. Not only touch points but also the distance to nearby objects can be roughly estimated. Multitouch detection does not require heavy processing and the surfaces can be very durable.

- Digital resistive:

Generally two conductive layers are coated with substances such as indium tin oxide. These layers are separated by an insulating layer, usually made of tiny silicon dots. The touchable panel is typically made of an exible hard coated outer membrane while the back panel is often a glass substrate.A controller swaps between giving electric current to one of the conductive layers and measuring it on the other. When users touch the display, the conductive layers are connected, establishing an electric current measured horizontally and vertically thanks to the controller swapping.

This technology has low power consumption, can be used with any kind of object. But reduces the transparency of the surface, the durability of the membrane is low and they hay low resolution. It also requires some pressure, so interaction is not as smooth as using other technologies.

- Surface Acoustic Wave (SAW):

Systems that use surface wave technology are similar to those that use infrared grid technology. Transmitting and receiving piezoelectric transducers, for both the X and Y axes, are mounted on a faceplate and ultra-sonic waves on a glass surface are created and directed by reflectors. By processing these to electronic signals and observing the changes when the faceplate is touched, it is possible to calculate the position of that

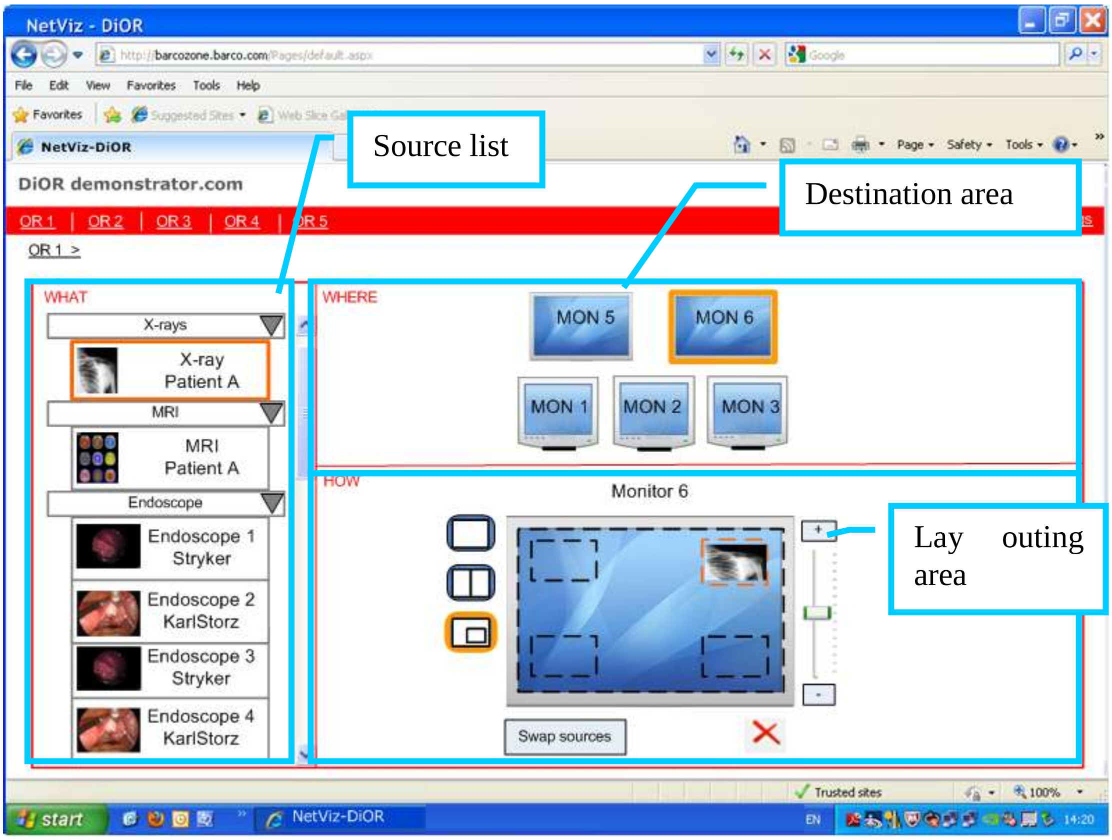
interaction. Most SAW systems can support at most dual touch, therefore these kinds of displays are not really multitouch, but are explained for completion.
This technology achieves very durable surfaces, since they can be ruggedized, allow a high clarity display, no pressure is needed, and most of the object can be used for interaction (they need to be able to absorb sound). But it is very sensitive to dirt on the surface, including water. The size is limited, as well as the number of simultaneously recognizable touches.
It is noteworthy that some of the interaction properties of these devices strongly depend on the hardware /technology used, and their GUI. The technology can limit the maximum number of simultaneous touches, the recognition frequency and resolution; or provide with additional information like distance from objects to surface additionally to touch in case of some capacitive sensors, or identifying touches with users, like the Diamond Touch (Dietz & Leigh, 2001). The hardware refers to the size and orientation of the surface, which dramatically determines the way to use it and consequently the GUI design. At this moment the technology is quite mature and robust, and there is also a strong research on this topic, so improvements can be expected in the near future. And the GUI design plays an essential role to take into consideration the strengths and weaknesses of the specific setup. The inclusion of multitouch into GUI is still novel and not well established, so the full potential of this UI is still to be unleashed. There is a need for some kind of standards to be agreed, although there are already several de-facto standard multitouch gestures and associated GUI actions like zooming, panning or rotating.
The main advantages of this UI are the direct interaction on the surface itself, the simultaneous interaction in the same surface and the possibility to resemble a electronic version of a standard blackboard, notebook or table, both in the physical appearance and in the way to interact with objects in it, making them natural since they mimic common everyday life interaction contexts.
On the other hand, multitouch surfaces are not very hygienic although in many cases the surfaces have an antibacterial treatment on them. They get dirty easily and the fact of multiple different people touching it can produce contempt in some cultures. Fingers are not as accurate as a pen for specific tasks also.
There are many commercial products available, from small sized tablets, to tabletops, walls or only screens. Among tablets, the most extended are the Apple iPad (capacitive screen), but the most important manufactures are releasing their versions like HP, Samsung, Dell, and Google. A recently created company, Notion Ink, has also presented an Android based tablet which has been received with big interest in the community because of its innovative GUI design, focused in multitouch interaction and some of its hardware characteristics. Google is also preparing a specific OS for tablets, completely focused in multitouch interaction, as an evolution of Android.
Among tabletops, Microsoft's Surface is the most known, initially with an ad-hoc programming API for Windows Vista, but now using Windows 7 and its built-in multitouch management. PQ Labs provides tabletops, walls and only screens, using different technologies, and their own API.
In the software side, Microsoft OS Windows 7 has gained some multitouch gesture management, as well as Linux (GTK+, Gnome). GUI designing API's like Qt or Windows Presentation Foundation in .Net have also added multitouch event management.

3.6 Tablet PC and GUI as mobile clinical assistant

An overview of this field is presented by the following concrete example. It is particular interesting to analise the issue of how to design a GUI for a tablet PC for the medical market.

Barco has already introduced tablet PC solutions into the medical market. They have investigated how a video management tool could be designed befitting that specific platform. The Cliniscape[3] is operated with a stylus. In order not to trouble the user with installations and software updates, the working frame in which the video management tool would operate is any type of web browser (Chrome, Mozilla Firefox, Internet Explorer, etc.)

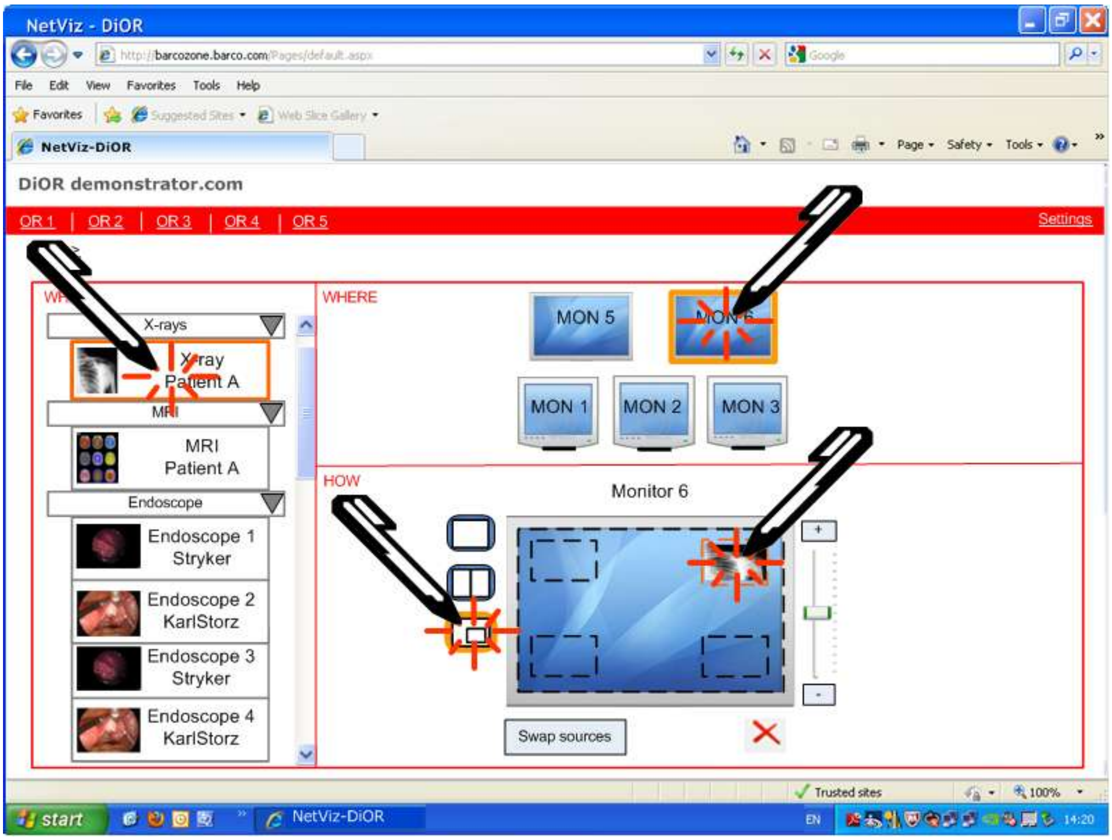
Workflow



The different sources, that are available in the hospital network, are organized according to type of source in a list. Each source category is represented by a pane. From this list the user selects the source(s) he/she wants displayed on a specific monitor in the OR. Each source is represented by a thumbnail and a label, for easy source identification.

[3] http://www.barco.com/en/medical/product/2236

For the selected OR, all destinations (i.e. monitors) that are available in the network are displayed. The monitors are identified by a label as well as a representative image of the type of monitor.
The video management tool allows the user to make combinations of sources on the monitor, called layouts. In general, three types of layouts are used within the OR:
PIP (picture in picture): a small source in one of the corners of the monitor on top of a full source.
PAP (picture and picture): two equally large sources displayed on the monitor.
FULL: one source displayed over the entire monitor surface.
The first touch tablet PCs (i.e. PDAs) were operated as form like interfaces, where the main gesture was simply ticking with the stylus on the touch screen to complete an action (selecting, typing, scrolling, activating, etc.). However, because of technological evolutions, modern day touch screens operated with a stylus support gestures such as drag & drop and press & hold. The question rose, which of these gesture concepts (tick vs. drag & drop) are known to the targeted users. If the more recent concept of dragging & dropping with a stylus is not known to the users, as was assumed at the time, then this was not the gesture to be implemented.



Possible scenario

The surgeon sets up Patient A's x-ray on monitor 6. But he needs a larger area available to bring on the endoscopic camera when the surgery starts:

A possible procedure would be:

1. Tick to select monitor 6
2. Tick to select x-ray thumbnail of patient X
3. Tick to select the PIP layout
4. Tick to select destination of source on the layout area

I-Pad

A number of technological evolutions (touch screens, improvement of mobile connectivity, improvement of mobile platforms, etc.) in the past decade culminated in a tablet PC revolution of which the iPad is the most flagrant and most known result. Currently, iPad holds 75% of the tablet PC market share, as online research quickly supports. It can easily be assumed that a number of those iPad users have a paramedical profession. More specific online market researches indicated that 1 out of 5 physicians are interested in using the iPad in the medical context. In some hospitals the iPad is already adopted as a standard working tool.
The installation and update process of an iPad app requires only minimal intervention of the user. With a simple couple of taps, an app is installed on the iPad or an update is executed. When connected and synchronized with the app store, easy retrieval of installed apps after damage or loss is supported.

Initial considerations

With the iPad some considerations have to be taken into account. One of them is: developing for iPad means developing an iPad app. This means in-house knowledge of app development is required or the development needs to be outsourced. Secondly, traditionally, apps are marketed through the app store. This means less control over the distribution process.

In order to bypass these possible restrictions, a video management tool can also be implemented in a browser environment (i.e. Safari) on the iPad. However, here issues rise about the browser not supporting typical iPad gestures such as swiping or dragging and dropping. Although technical limitations that will be overcome by due time, currently, if the application is not in correspondence of the platform, intuitivity and thus usability is killed.

Note

The GUI designs below have been designed together by Human Interface Group and Barco. They have investigated the specific user needs in this context for the operating rooms and using an iPad app framework.

Workflow management

The different sources, that are available in the hospital network, are organized in a carrousel. From this carrousel, the user selects the source(s) he/she wants displayed on a specific monitor in the OR. Each source is represented by a thumbnail and a label, for easy source identification.

For the selected OR, all destinations (i.e. monitors) that are available in the network are displayed. The monitors are identified by a label as well as a representative image of the type of monitor.

The video management tool allows the user to make combinations of sources on the monitor, called layouts. In general, three types of layouts are used within the OR:

- PIP (picture in picture): a small source in one of the corners of the monitor on top of a full source.
- PAP (picture and picture): two equally large sources displayed on the monitor.
- FULL: one source displayed over the entire monitor surface.

Because of the unique concept of the platform, i.e. the iPad, and the revolutionary gesture concept behind it, there was no need for a lay outing area in the iPad GUI. In the gesture chapter this is explained more in detail.

Drag & drop

Possible scenario

The surgeon sets up the patient's vital information, coming from instrument HP XR-710, on monitor 1:

The procedure would be:

- Touch to select source “Vitals”ok
- Drag & drop source thumbnail to monitor 1

Note

The foreseen user-machine communication makes sure that the user is informed about what source is dropped where and in what layout:

- What source: during drag& drop a copy of the source's thumbnail sticks to the user's finger.
- Where: when the user comes near a monitor, the monitor enlarges.
- What layout: upon approach, a highlight area appears on the monitor indicating how the thumbnail will be dropped.

Swipe

Possible scenario

The surgeon wants to search for a source, which is not displayed in the carrousel:
The procedure would be:

- Swipe the carrousel from right to left, to navigate to the next set of sources.

Lay outing

As mentioned before, the iPad concept allows specific human machine interaction in regards to lay outing. If, e.g. a user would like to set up two sources on a monitor, after having set up the first source, the drop zone in the targeted area is highlighted, clearly indicating were the source would be set up on the monitor.

3.6.1 Large scale multitouch surfaces

Although due to hygiene restrictions touch based interaction is not permitted in the Operating Room (OR), there are some projects involving support software applications for the operations, like surgery planning.
There are two developments for Microsoft Surface, VitruView[4] which is a prototype designed to help with angiography procedures in a catheter lab and the Infusion company has developed a Doctor-Patient Consultation Interface[5], which permits doctors to show complex medical concepts to the patients using graphics and simple interaction procedures.
The company Brainlab has developed a commercially available multitouch table called Digital LightBox which allows surgeons and physicians to instantly manipulate digital medical data. One of the applications developed by Brainlab using this platform is

[4] http://www.interknowlogy.com/Content/VitruView_single_page.pdf
[5] http://www.infusion.com/Case-Study.aspx?cat=4&sub=5&id=8

called Orthopedic Templating Software[6], and allows surgery planning to be extended to the Operating Room.

The Norrkoping Visualization centre in Switzerland has developed a multitouch table for forensic procedures called Virtual Autopsy Table[7], which permits navigation on CT imaging. Recently Sectra AB[8] is offering it commercially for radiology, mammography and orthopaedic departments.

Figure 3: Digital LightBox® (BrainLab®)

3.7 Haptic devices

Introduction

Haptic devices refer to the set of UI where interaction is carried out by means of the sense of touch. In order to realize the importance of the touch sense in virtual and real environments, the reader is referred to (Robles-De-La-Torre, 2006).

In medicine, the concept of haptics is used mainly for surgical simulation and serves at least two purposes: kinaesthetic and cognitive. These types of interfaces provide from one hand the sensation of movement to the user and therefore it significantly enhances it surgical performance. Second, it helps to distinguish between tissues by testing their mechanical properties thanks to the haptic force feedback. The addition of a haptic feedback in a simulation system highly increases the complexity and the required computational power: it leads to an increase by a factor 10 of the required bandwidth, synchronization between visual and haptic displays, force computation. Some important features for a haptic interface are dynamic range, bandwidths, degrees of freedom, structural friction and stiffness. Dynamic range is the maximum force divided by the interface friction. High bandwidths are important for short time delays and overall system stability. Friction is the force resisting the relative lateral (tangential) motion of haptic arm in contact. The degrees of freedom are the set of independent

[6] http://www.brainlab.com/art/2829/4/orthopedic-templating-software/
[7] http://www.tii.se/projects/autopsy
[8] http://www.sectra.com/medical/visualization/

displacements and/or rotations that specify completely the displaced position and orientation of the body or system. Sustained force levels are usually much smaller than maximum output force produced by haptic interfaces. Stiffness is the resistance of an elastic body to deformation by an applied force during the contact with the haptic tip.
Only a few papers have assessed the importance of haptic feedback in surgery (Marcus, 1996). In general, it is accepted that the combination of visual and haptics is optimal for surgery training or pre-planning.

3.7.1 Haptic Devices and basic concepts

Haptic is from the Greek "haptesthai," meaning to touch. Usually used in a plural form (haptics), it means the science and physiology of the sense of touch. It is related to technology that interfaces to the user via the sense of touch by applying forces, vibrations, and/or motions to the user. The field of haptics is growing rapidly and is inherently multidisciplinary and in many areas, including robotics, experimental psychology, biology, computer science, systems and control, and others.
The main human structure associated with the sense of touch is the hand. It is extraordinarily complex: several types of receptors are in the skin and send trough the nerves information back to the central nervous system and the point of contact. The hand is composed of 27 bones and 40 muscles which offers a big dexterity. This concept is quantified using the degrees of freedom (movement afforded by a single joint). Since the human hand contains 22 joints, it allows movement with 22 degrees of freedom. The skin covering the hand is a rich of receptors and nerves is a source of sensations for the brain and spinal cord.
The haptic feedback is usually a conjunction of two types: kinaesthetic and tactile.
Kinaesthetic information concerns physical forces applied to an object and returned from that object. It takes advantage of human proprioception, the awareness of body position through the muscle and tendon positions. It deals with contours, shapes and sensations like the resistance and weight of objects. Tactile sensations are often included under the general term of haptics. These sensations incorporate vibrations and surface textures and are detected by receptors close to the skin. It is related to roughness, friction, and somatic properties, which includes changes perceived during static contact with the skin, such as temperature. In the specific, known as proprioceptors, these receptors carry signals to the brain, where they are processed by the somatosensory region of the cerebral cortex. The muscle spindle is one type of proprioceptor that provides information about changes in muscle length. The Golgi tendon organ is another type of proprioceptor that provides information about changes in muscle tension. The brain processes this kinesthetic information to provide a sense of the baseball's gross size and shape, as well as its position relative to the hand, arm and body.
There are several commercial haptic interfaces characterized by software to determine the forces that result when a user's virtual identity interacts with an object and a device through which those forces can be applied to the user.

Figure 4: Example of force-feedback glove with pneumatic pistons to simulate grasping (courtesy of Human Machine interface laboratory of Rutgers University)

The actual process used by the software to perform its calculations is called haptic rendering. A common rendering method uses polyhedral models to represent objects in the virtual world. These 3-D modelscan accurately portray a variety of shapes and can calculate touch data by evaluating how force lines interact with the various faces of the object. Such 3-D objects can be made to feel solid and can have surface texture.

The PHANTOM® interface from SensAble Technologies[9] (see Figure 38) was one of the first haptic systems to be sold commercially. Its success lies in its simplicity. Instead of trying to display information from many different points, this haptic device simulates touching at a single point of contact. It achieves this through a stylus which is connected to a lamp-like arm. Three small motors give force feedback to the user by exerting pressure on the stylus. Therefore, a user can feel the elasticity of a virtual balloon or the solidity of a brick wall. He or she can also feel texture, temperature and weight.

The stylus can be customized so that it closely resembles just about any object. For example, it can be fitted with a syringe attachment to simulate what it feels like to pierce skin and muscle when giving a shot.

[9] http://www.sensable.com/

Figure 5: Types of haptic interfaces: Omni® (left) and phantom Desktop® (right). Courtesy of Sensable® Tech.

The CyberGrasp® system, another commercially available haptic interface from Immersion Corporation Corporation[10] takes a different approach. This device fits over the user's entire hand like an exoskeleton and adds resistive force feedback to each finger. Five actuators produce the forces, which are transmitted along tendons that connect the fingertips to the exoskeleton. With the CyberGrasp® system, users are able to feel the size and shape of virtual objects that only exist in a computer-generated world. To make sure a user's fingers do not penetrate or crush a virtual solid object, the actuators can be individually programmed to match the object's physical properties. The CyberTouch® (another Immersion Corporation product) uses six lectromechanical vibrators placed on the back of the fingers and in the palm. These actuators produce vibrations of 0-125 Hz, with force amplitude of 1.2 N at 125 Hz.

Researchers at Carnegie Mellon University are experimenting with a haptic interface that does not rely on actuated linkage or cable devices. Instead, their interface uses a powerful electromagnet to levitate a handle that looks a bit like a joystick. The user manipulates the levitated tool handle to interact with computed environments. As she moves and rotates the handle, she can feel the motion, shape, resistance and surface texture of simulated objects. This is one of the big advantages of a levitation-based technology: It reduces friction and other interference so the user experiences less distraction and remains immersed in the virtual environment. It also allows constrained motion in six degrees of freedom (compared to the entry-level Phantom interface, which only allows for three active degrees of freedom).

The one disadvantage of the magnetic levitation haptic interface is its footprint. An entire cabinet is required to house the maglev device, power supplies, amplifiers and control processors. The user handle protrudes from a bowl embedded in the cabinet top.

[10] http://www.immersion.com/

Figure 6: the Cybergrasp ® (left) and the Cybertouch® (right). Courtesy of Immersion®.

Another human computer interface very simple but effective is a foot pedal.

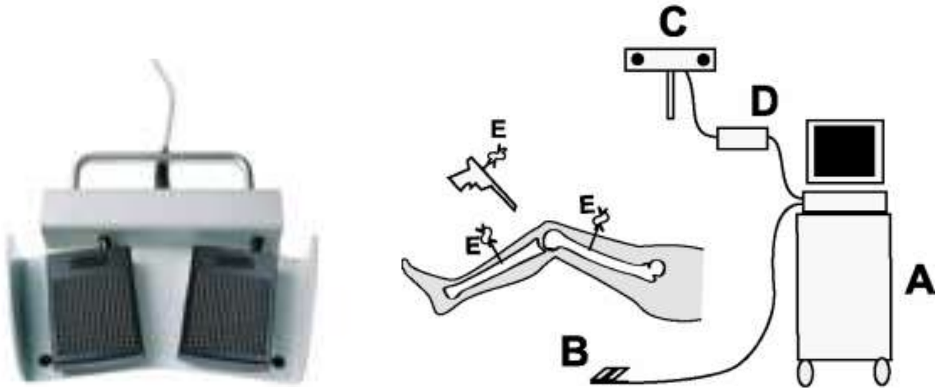


Figure 7: On the left: foot pedal. On the right: example of the use of foot pedal as a component of a typical CAOS system: A. surgical navigation station; B. foot pedal (input device); C. position tracker (localizer); D. localizer interface unit; E. tracking markers(DiGioia, Mor, Jaramaz, & BAch, 2005)**.**

This choice can leave the surgeon's hands free for other work, which is especially important in order to control data collected during surgical action:

- point clouds collection for patient registration;
- recording tool positions for stereotactic surgery;
- controlling the X-Ray, ablation and pacing systems;
- robotics (for example for "da Vinci" Robotics Surgery).

3.7.2 Example of application of haptic devices in medicine: Surgical Simulation

Previous studies show that the use of force feedback during the execution of surgical tasks can be a big help. Some researches (Wagner, Stylopoulos, & Howe, n d) have collected results in performing the dissection of an artery with and without force feedback. They have shown that force feedback significantly reduced the number of errors and the overall level of applied force. Some researchers (Hu, G Tholey, J P Desai, & A E Castellanos, 2004; Gregory Tholey & Jaydev P. Desai, 2007) have been asked subjects to perform a soft-tissue identification task in a physical model, and found that haptic feedback significantly enhanced subjects' ability to distinguish among tissue types. Force feedback reduces applied forces in a catheter insertion task (Kazi, 2001).

These results confirm the intuition that haptic feedback is critical to the fine dexterous manipulation required for surgery.

Simulators are particularly focused on minimally invasive techniques especially video-surgery (endoscopy, laparoscopy) in which particularly skill have to be developed. In laparoscopy for instance, the surgical procedure is made more complex by the limited number of degrees of freedom of each surgical instrument. Moreover, high level of hand-eye coordination is requested to use the fixed point on the patient's abdomen incisions especially considering that the surgeon cannot see his hand on the monitor. In addition, the development of minimally invasive techniques has reduced the sense of touch compared to open surgery, surgeons must rely more on the feeling of net forces resulting from tool-tissue interactions and need more training to operate successfully on patients. Haptics is a valuable tool especially in minimally invasive surgical simulation and training (Basdogan, De Rensselaer, Muniyandi, & Srinivasan, 2004). Such systems bring a greater flexibility by providing scenarios including different types of pathologies. Furthermore, thanks to the development of medical image reconstruction algorithms, surgery simulation allows surgeons to verify and optimize the surgical procedure (gestures and strategy) on a specific patient case.

Webster et al. (Webster et al., 2003) present a haptic simulation environment for laparoscopic cholecystectomy, and Montgomery et al. (Montgomery et al., n d) present a simulation environment for laparoscopic hysteroscopy; both projects focus on haptic interaction with deformable tissue. Another haptic simulator for interventional cardiology procedures, incorporating blood flow models and models of cardiopulmonary physiology has been presented (Cotin et al., 2000).

The success of using haptic devices in medical training simulators has already been obtained by several commercial companies working in this field (Immersion Medical, Surgical Science, Mentice, and Reachin Technologies, for example) and other research studies [33-37].

Many training simulators can already be found on the market. Most of these can be used on real data.

Surgical Simulator: The LaparoscopyVR Virtual-Reality System (IMMERSION)

The LapVR Surgical Simulator uses the latest advances in technology, appropriate interactive 3D models, haptic force feedback, and performance tracking and evaluation to help decrease the learning curve in laparoscopic surgery

Endoscopy AccuTouch System (IMMERSION)

The AccuTouch® endoscopy surgical simulator's modular design allows cost effective medical training of multiple disciplines on the same platform:
- Flexible bronchoscopy
- Upper gastrointestinal flexible endoscopy
- Lower gastrointestinal flexible endoscopy.

The robotic interface provides realistic forces, emulating the feel of the real procedure.
Virtual-reality patients respond in a physiologically accurate manner.
Real-time graphics and audio feedback combine with haptic feedback.
Anatomic models developed from actual patient data provide increasingly challenging anatomy
Multimedia didactic content supports independent learning

CathLabVR System (IMMERSION)

The virtual-reality CathLabVR System fills roughly the same space as real cath lab equipment and includes:
Two monitors, one for displaying fluoroscopic views, Virtual Assistant functions, navigation control, and simulated patient information; the other for displaying physio, cine, and still images, controls for the C-arm — as well as total procedure running time, fluoroscopy and cine radiation time, and contrast instilled
A manifold for contrast instillation, balloons, balloon stents, guidewire, and catheter
A foot pedal used to capture cines and control fluoroscopy; a joystick to maneuver the simulated C-arm; and a keyboard and mouse to make onscreen selections
Multiple endovascular simulation modules cover a variety of situations and procedures:

- Coronary and peripheral vascular interventions
- Cardiac pacing
- Cardiac valve replacements
- Carotid interventions

Arthroscopy Surgical Simulation: insightArthroVR System (IMMERSION)
The insightArthroVR arthroscopy surgical simulator provides arthroscopy training on knees and shoulders in a controlled, stress-free, and virtual-reality environment.
The system, manufactured by GMV, includes:

- Realistic anatomical models validated by experts in arthroscopy and anatomy, including both healthy joints and a variety of pathologies
- A camera and multipurpose tool that adapts to different joints and arthroscopic techniques
- Skill indicators that allow for practitioner skills evaluation through configurable key performance indicators

- A training program in which the practitioner can advance through exercises of increasing difficulty

Vascular Access Virtual Reality Simulator (IMMERSION)

The Virtual I.V. system is a fully interactive self-directed learning system for training intravenous catheterization.
The system's superior 3D graphics provide realism and its force feedback simulates the feel of vascular access, providing an accurate, truly virtual reality training experience. Virtual patients respond with bleeding, bruising, and swelling.

The SensAble™ Dental Lab System

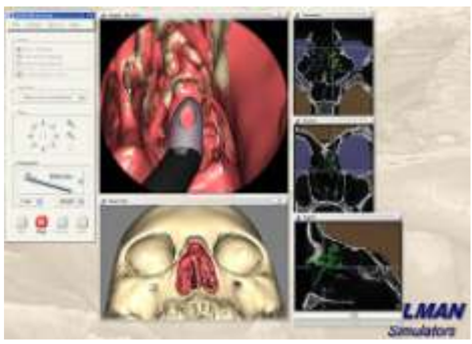
The SensAble™ Dental Lab System provides an integrated solution to scan, design and fabricate common dental restorations. It is the first dental CAD/CAM system to support the production process for partial frameworks, as well as full contour crown and bridge, including pressables (press over Metal, press over zirconia, and monolithic ceramic) porcelain fused metal, and full metal.

Neuroscience and Rehabilitation

The MotionMonitor, SensAble Technologies and SenseGraphics AB have partnered to develop the latest in virtual reality immersive systems. Now for the first time, stereoscopic visualization displays are available as integrated turn-key systems with haptic feedback, body tracking and eye tracking, all powered by The MotionMonitor presentation and analysis software. This unique configuration is an ideal product for research in motor control, robotics and assistive rehabilitation studies.

Mediseus SDS3000 Surgical Drilling Simulator (Medic Vision)

Medic Vision is a world leader in the provision and facilitation of end to end healthcare training solutions. This is achieved through design and management of skills centres and through the deployment of world recognised training courses and the application of technology in an effort to up skill all health care professionals to the highest quality standard to meet the rising demands of the healthcare market. Mediseus Temporal Bone perfecting the indicate skills of temporal bone surgery.



SinuSurg (VOXEL-MAN)

VOXEL-MAN SinuSurg is an exciting new type of simulator for endonasal sinus surgery which allows to realistically explore the anatomy of the endonasal region. The system provides endoscopic and microscopic views, a wide selection of tools which are controlled with a force feedback device and anatomical models with various organs at risk.

The screenshot below shows the user interface with an endoscopic view through the opened ground lamella (at center), the control panel (left), and three cross-sectional images (right) which are automatically positioned at the tip of the tool. On the cross-sections, the tissue which has already been removed during the intervention is marked in green.

TempoSurg (VOXEL-MAN)
The VOXEL-MAN TempoSurg simulator is a unique tool for **training** and **planning** both the classical and the navigated surgical access to the middle ear. The system is based on virtual 3D models of the skull base derived from high-resolution CT data.

Episim™ (YANTRIC)
The Epidural Injection Simulator (Episim) allows trainees to inject a needle into the epidural space of a virtual patient with a sense of touch. The Episim is particularly suitable for procedural training for practitioners in the military, as well as for trainees in civilian medicine such as obstetrics/gynecology, anesthesia and pain management

Lapsim (YANTRIC)
The Laparoscopic Simulator (Lapsim) is a training system based on the same simulation platform as the Episim. The Lapsim is a two-handed system that allows users to learn basic manipulative skills in a minimally invasive environment.

VirTeasy Implant Pro (DIDHAPTIC)
VirTeasy Implant Pro has created the missing link between theory and clinical training. High level of practice and expertise of students trained with our simulator will be the added value of your training center. Using **VirTeasy Implant Pro**, practitioners will explore and learn implantology in breadth and depth thanks to virtual reality's ability to simulate all types of anatomical and clinical cases. Those cases are either predefined in our equipment by experts or programmed by the teacher himself, using our large and open database.

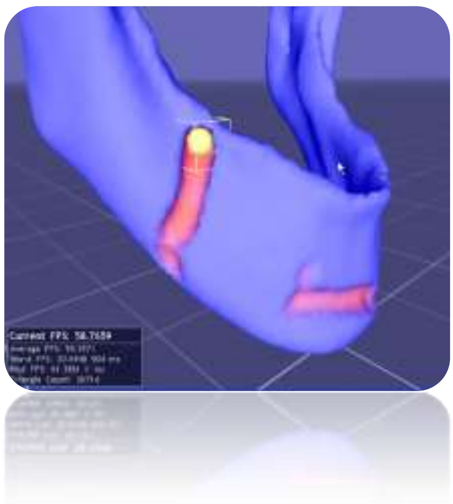
Simodont dental Trainer (MOOG)
The dental trainer provides high-end dental simulation and training. It is a complete, proven training system for dental schools committed to helping students progress faster and professors track progress and plan student work efficiently.

3.7.3 Pre-intervention simulations

As indicated, these simulators can be used to plan intervention. Some simulators have specifically designed to repeat difficult intervention.
Part of these simulations is made without any haptic devices.

Haptic device are required only for specific preparation to train the surgeon to works on a difficult act before its realisation.

Surgical Science (Sweden) develops high-quality tools for the Assessment, Training and Certification of medical professionals.
Using cutting-edge simulation technology and wide-ranging knowledge of the needs of the medical community, they are committed to developing tools that will help train safer surgeons faster, using systems to build skills that actually transfer right into the operating room. Thanks to LapSim, Surgical Science showed a significant beneficial impact of warm-up on laparoscopic performance in the Operating P. The suggested program is short, easy to perform, and therefore realistic to implement in the daily life in a busy surgical department. This will potentially improve the procedural outcome and contribute to improved patient safety and better utilization of Operating Room resources.
For these types of simulation, works from CEA-List during SKILLS project must be describe. The development has been made for maxillo-facial surgery.



The drilling of different mandible creates various behaviour of the tool. This can surprise the surgeon and induce a risk for the patient.

3.7.4 Example of application of haptic devices in medicine: Robotics

The state of art in surgical robotics is the da Vinci Surgical System (by Intuitive Surgical) which is designed to facilitate complex surgery using a minimally invasive approach. The surgeon sits at the console and looks through two eye holes at a 3-D image of the procedure, meanwhile manoeuvring the arms with two foot pedals and two hand controllers. The da Vinci System scales, filters and translates the surgeon's hand movements into more precise micro-movements of the instruments, which operate through small incisions in the body. It is important to notice that this system which could be considered a complex fusion of different interfacing technologies doesn't provide surgeons with any force feedback. Some experiments confirmed force feedback plays a significant role in minimally invasive surgery (Wagner, Stylopoulos, & Howe, n d) . Because of this, the loss of haptic sense in the robotic system remains one of the big limitations.

Figure 8: da Vinci surgical system (Intuitive Surgery). It consists of an ergonomic user haptic interface, co-axial hand-eye alignment, stereoscopic viewer, and instruments with seven degrees of freedom, fingertip control of the surgical gestures.

3.8 Plug computer

Plug computer is a small form factor server for use in several diverse environments. Compared to normal PC, plug computers are lower cost, consume less power, often do not have a video card, and are intended to be powered up at all times. Although plug computers are often enclosed in an AC power plug or AC adapter, the term "plug" also refers to "plug and play" appliance-like devices which may be in any form factor. Those systems are suitable for running a media server, back-up services, file sharing and remote access functions such devices can be used as a bridge between in home protocols such as Digital Living Network Alliance (DLNA) & Server Message Block (SMB) and cloud based services.
Plug Computing has been quickly expanding, bringing users new devices, services, and value-added applications, as well as delivering advanced avenues for network connectivity. The new embedded Wi-Fi, Bluetooth and built-in hard drive available product extend the use of plug computing into new applications including management of medical records.

Figure 9: Marvell Technology Group's[11] SheevaPlug plug computer with iPhone (approx 115 mm x 60 mm) for scale

3.9 Advanced visualization

3.9.1 Widescreen Displays

This is a novel aspect ratio for displays introduced by Philips in 2010. Nominally 21:9 (2.33) aspect TVs have been introduced by Philips and Vizio (the latter using an LCD from AU Optronics) as “cinema” displays, though the resolution is more precisely 2560x1080 = 2.37, and the aspect ratio is not standardized in HDTV12.
At this moment both available displays are LED tv-s, focused on home cinema, and not computer monitors.

3.9.2 Pico Beamers

These devices, also called pocket projectors or mobile projectors are a recent trend to miniaturize video projectors. The main purposes are to increase the mobility/portability of the devices and to provide with big size screen to portable devices like mobile phones.
The conventional approach involves connecting them to an image production device, like a mobile phone, through some kind of port, like USB.
Nevertheless, most of them have become themselves autonomous tools able to show different file formats, without the need to connecting them to any other device. This is achieved using internal memory on the projectors or including flash card readers on the device.
Currently the three most important imager technologies competing in the market are:

1. Texas Instruments’s Digital Light Processing (DLP).

[11] http://www.marvell.com/
[12] http://en.wikipedia.org/wiki/Aspect_ratio_(image)

2. Microvision’s beam-steering.
3. LCoS (Liquid crystal on silicon).

The advantages and disadvantages of each technology vary. For example while DLP typically has slightly lower resolution than their LCoS counterparts due to the tiny mirrors used in DLP technology, 3-LED DLP projectors are generally regarded as having a higher contrast, better efficiency and lower power consumption as opposed color-sequential LCoS units and better colour quality than white LED LCoS units. Laser scanning projectors such as Microvision's ShowX and AAXA's L1 offer very good color gamut and low power consumption due to the use of lasers as the light source and also present an image that is always in focus.

Currently the best selling pico beamer companies are Optoma (PK301, PK201, PK101, and PK102), 3M (MPro-150) and Microvision (ShowWX+).

A User Interface called SixthSense[13], has been developed combining a mobile phone, a camera, some markers on the user’s hands and a pico projector. The user can project an application GUI on any surface, including his own hand and interact with it using hand gestures.

Figure 10: SixthSense[17] system

3.9.3 Augmented Reality

The goal of Augmented Reality (AR) is to add information and meaning to a real view of the user. For example, by superimposing imaging data from an MRI or 3D reconstruction of particular regions of interest onto a patient’s body, AR can help a surgeon to visualize a tumor that has to be removed ((De Mauro, Raczkowsky, Halatsch, & Wörn, 2009) or [40]). In those cases, the technology used might include head mounted displays or common biomedical devices (microscopes, endoscopes or

[13] http://www.pranavmistry.com/projects/sixthsense/

monitors) that maps data to the patient lying on the operating table. In other cases, augmented reality might add audio commentary, location data, historical context, or other forms of content that can make a user's experience of a thing or a place more meaningful. A review on the challenges related to the use of AR in the operating room focused on cardiac image guidance has been shown in (Linte, White, Eagleson, Guiraudon, & Peters, 2010).

The most advanced examples of the clinical use of AR in surgery are given by the advanced microscopes for neurosurgery which are able to show region of interests directly inside the oculars. They work with stereotactic system able to localize patient, surgical tools and microscope position.

Figure 11: Example of AR for neurosurgical application. The Leica DI C500 is an image ijection device for Leica microscopes. Several type of information (i.e. 3D reconstructions, patient preoperative images, etc.) can be visualized inside one of the ocular (image on the right).

There many researches on the application of AR concepts inside the surgical workflow but they are still "experimental" and not accepted by the medical community. The main reason is related with the not-acceptance of the user interface usually used for AR (for example HMD seem to be not rejected by surgeons because too far from the other medical device). The implementation of AR directly using medical optical device (i.e. microscopes, endoscopes or displays) is more accepted by the professionals in the field.

3.9.4 Three dimensional Visualization

Stereoscopic 3D displays provide different perspective views to the left and right eye. As in natural vision, the differences in perspective are immediately used by the human visual system to create a volume perception of natural or computer-generated scenes. These systems permit 3D perception on the content seen by the user. In order to accomplish it, several devices and techniques have been proposed. The advantages of perceived 3D in visualization are obvious, but actual systems also have several drawbacks. Many of them require the user to wear some kind of device, which can be very cumbersome. In some cases they are restricted to one user. These devices are usually expensive. The use of these devices for a continuous extended period of time usually produces strain on the user and in some cases even a dizziness feeling.

Holographic techniques can record and reproduce the properties of light waves almost to perfection of a 3D volume, making them a very close approximation of an ideal free-viewing 3D technique. Unfortunately, these techniques are still in their infancy.

Volumetric displays produce a real 3D visualization into a constrained and closed physical volume space. In volumetric displays the portrayed foreground objects appear transparent, since the light energy addressed to points in space cannot be absorbed or blocked by (active) foreground pixels. Practical applications seem to be limited to fields where the objects of interest are easily iconized or represented by wireframe models.

For an extended review on 3D displays, the reader is referred to (Pastoor, 2005). Next, each type of the presented 3D visualization techniques is covered.

3.9.5 Aided-viewing stereoscopic systems

Stereoscopic devices create two different views of the content displayed; one for each eye, with a little displacement between them, and the brain creates the illusion of 3D. A pair of special glasses filters the displayed content so each of the images is only seen by one eye. There are four different image multiplexing techniques. The first one uses two complementary colour lenses (anaglyph display), one for each eye. The displayed content is processed so that the color of the image for each eye can only be seen through one of the filters. This process usually reduces the color rendition. The Infitec system developed by DaimlerChrysler and Barco uses three-colour wavelength-sensitive notch filters with peak transmissions in the red, green and blue spectral areas. The transmissions are centred about slightly different peak frequencies of the left and right-eye images, different enough to separate the views, but close enough to avoid binocular rivalry. The Infitec system provides full colour rendition. The second technique requires a time synchronization mechanism between the display device and the glasses. The content is displayed at double framerate (>60 fps.) alternating an image for one eye and the other. When the left eye image is being shown, a signal sent to the glasses makes the right lens opaque and the left transparent, and when the right image is being displayed the left lens becomes opaque while the right lens becomes transparent. This second technique offers better immersion and image quality but it requires more complex hardware, including a high framerate content generation and display. A third technique uses polarizing filters in order to multiplex both eye images. Two video projectors generate the two eye views. Each projector has a polarizing filter in front of it with a different polarizing angle. Then a pair of glasses with properly oriented polarizing filters for each eye provides only with the suitable image to each eye. This technique offers full color and resolution, but over 60% of light amount is lost by the polarizing filter. The last technique uses location multiplexing. Each eye view is created in a different place and it is sent to the proper eye through separated channels (e.g.: using lenses, mirrors and optical fibres). This last technique includes the

Head Mount Displays (HMD), and Binocular Omni-Orientation Monitor (BOOM) displays, for fixed, but adjustable accommodation distances, among others.
These technologies are quite mature and many companies provide robust solutions involving the use of some kind of glasses like NVidia's 3D Vision, which combines a GPU, specialized 3D glasses, software, and certified displays and projectors. Many other manufactures, including Samsung, Panasonic also produce 3D displays used with some kind of glasses.

3.9.6 Head mounted displays (HMD)

This device is composed of some kind of glasses with small display screens placed in the eyes. Some of these devices use transparent screens (optical see-through), being also valid for Augmented Reality systems, while others have opaque screens (video see-through). In both cases, two slightly different images are sent to each eye, to achieve the effect of 3D. This kind of system is usually equipped with some kind of tracking device to obtain the 3D orientation and in some cases the position of the user. The perceived images may subtend a large field of view of up to 140º (horizontal) by 90º (vertical). HMDs allow free head movement without losing screen contact, thus avoiding musculoskeletal problems. All these characteristics permit a high immersion level. Latencies and tracking errors produce odd sensations on the user. A disadvantage of see-through HMDs is that the viewer must direct his or her regard towards a dim background in order to perceive a clear HMD image.
Some companies like eMagin, Sensics and Vuzix produce commercial HMD devices. In (Liu, Jenkins, & Sanderson, 2009) a first approach to the use of HMD in the Operating Room is presented. The purpose is to increase the awareness of the medical staff on the vital signs of the patient.

3.9.7 Binocular Omni-Orientation Monitor displays

The Binocular Omni-Orientation Monitor (BOOM) was designed to release the user from the encumbrance of wearing an HMD (Pastoor, 2005). Two miniature displays are accommodated in a case, which is mechanically supported by a counterweighted, six-degrees-of-freedom arm. The user regards the stereo images as if looking through binoculars. Tracking is implemented by optical shaft encoders at the joints of the boom. The monitor case is moved either with hand-held handles or with the head (like an HMD).
This device type is commented just for completion, but their commercial availability has been discontinued by most of the companies, like Fakespace Systems BOOM HF.

3.9.8 Auto-stereoscopic systems

These devices permit a three-dimensional perception of the contents in the display without the use of any special device on the user, like glasses. Some of them, like the approach followed by See Real, use an optical eye tracking system to adjust the displayed content according to the position of the user. Unfortunately, this example is only valid for one user at the same time. Others make use of parallax barriers or

lenticular lenses. When the user is between a screen viewing angle range, each eye perceives a different view of the content. This permits several users at the same time in different angles, but the technology produces dead viewing angles where the 3D effect is not perceived, and there are a limited number of distinct views. Additionally, the 3D perceived resolution is a fraction of the screen resolution, because several views are artificially created in different viewing angles with a limited pixel resolution amount.
Several companies offer different solutions like Magnetic 3D, Alioscopy, 3D Super, Spatial View and Zero Creative.
TrueVision offers specific flat HD panels for 3D visualization in the Operating Room, and also 3D surgical cameras for microsurgery. In (Ruijters & Zinger, n d) the technical difficulties of using this technology in the Operating Room are exposed. Mainly, the perceived depth information must be consistent to the underlying data, and simultaneously the amount of data required for this 3D perception must be minimized due to transmission bandwidth limitations.

3.9.9 Holography

Holographic techniques can record and reproduce the properties of light waves, i.e.: amplitude (luminance), wavelength (chroma) and phase differences, almost to perfection, making them a very close approximation of an ideal free-viewing 3D technique. Recording requires coherent light to illuminate both the scene and the camera target (used without front lenses). For replay, the recorded interference pattern is again illuminated with coherent light. Diffraction (amplitude hologram) or phase modulation (phase hologram) will create an exact reproduction of the original wavefront (Pastoor, 2005).
Holograms cannot be recorded with natural lighting; therefore the scene source can only be a computer-generated model. This technology is still in research stage due to several technological limitations, like the data transfer speed required. Nevertheless, some products are already available like IO2 Heliodisplay, which projects full colour images in the air (it requires the user to wear 3D glasses) and RealFiction Dreamoc which provides a dazzling combination of holographic-like, free floating video images, with a display of the physical product.

Figure 12: IO2 Heliodisplay

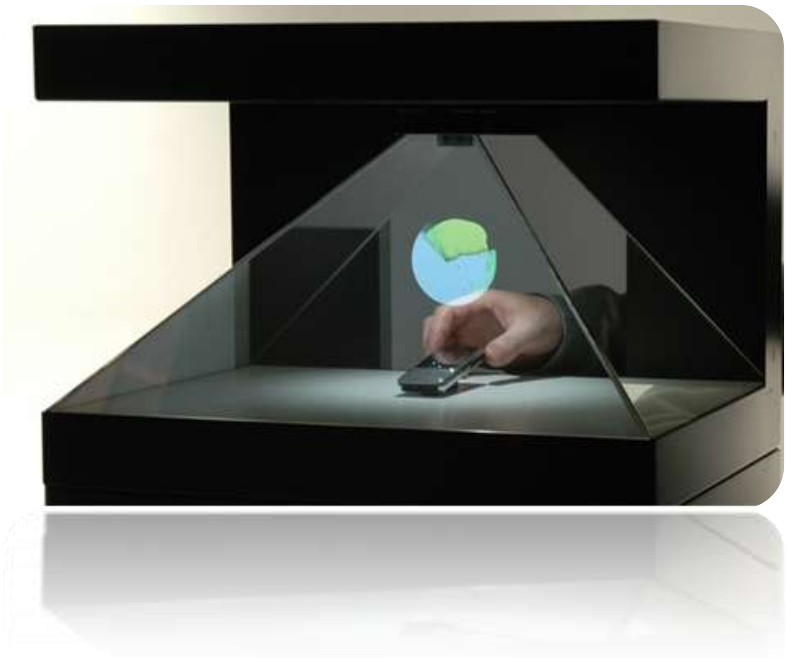


Figure 13: RealFiction Dreamoc

3.9.10 Volumetric displays

Volumetric displays produce volume-filling imagery. 3D image points (voxels) are projected to definite loci in a physical volume of space where they appear either on a real surface, or in translucent (aerial) images forming a stack of distinct depth planes. With the first type of system, a self-luminous or light reflecting medium is used which either occupies the volume permanently or sweeps it out periodically. Technical solutions range from the utilization of fluorescent gas with external excitation through intersecting rays of infrared light over rotating or linearly moved LED panels to specially shape rotating projection screens. Rotating screens have been implemented, e.g., in the form of a disc, an Archimedian spiral or a helix, winding around the vertical axis.
The user can walk around the display and see the image volume from different angles.
Actuality Systems Perspecta and soon Sony Volumetric 3D are commercial volumetric displays.

Figure 14: Examples of volumetric displays. On the left, Actuality Systems Perspecta Volumetric Display. On the right, Sony Volumetric 3D.

In (Wang, Kao, & Liang, 2005) a Spectra volumetric display is used to visualize ultrasound data for intracardiac catheter manipulation tasks. Empirical results show that 3D visualization permits reducing the time spent. In addition (Geng, 2008) presents some preliminary satisfactory results in the field of radiation therapy planning (RTP) using a volumetric display to improve visualization.

4. Overview on the relation between disciplines and related technology

In the next table, an overview of the relation between mentioned technologies and the disciplines in which they are used is presented.

Technology	Disciplines	Status	Examples
Speech recognition and voice control	Almost all the disciplines (especially abdominal surgery & Orthopedics) Electronic Medical Records	product product	Stryker-sidne® VOICE CONTROL for: • Endoscopic Camera • Light source • Digital Capture Device • Insufflator • Arthroscopic Pum • In-light Camera • Surgical Bed • Surgical Lights • Electrosurgical Generators ADVANCES IN SPEECH RECOGNITION 2010, Part 3, 247-273, DOI: 10.1007/978-1-4419-5951-5_11
Gesture Recognition	Manipulation of medical images in all surgeries OR	research	Feied, C., Gillam, M., Wachs, J., Handler, Jonathan, Stern, H., & Smith, M. (2006). A real-time gesture interface for hands-free control of electronic medical records. AMIA Annual Symposium proceedings / AMIA Symposium. AMIA Symposium, 920.
Touchscreen	Manipulation, medical Images, workflow management in several the clinical environments and surgeries	product	Digital LightBox® (BrainLab®) Cliniscape® (Barco®)
Haptic devices	Robot manipulation	product	DaVinci® (Intuitive Surgery®)

	in: cardiothoracic, colorectal, general, gynecology, head and neck surgery, urology Foot pedal in many surgeries (i.e. controlling X-Ray, ablation and in conjunction with DaVinci surgeries) Simulation and training in the several surgeries (laparoscopy, cholecystectomy, hysteroscopy, bronchoscopy, arthroscopy, C-arm simulation, dental surgery, ENT surgery)	 product product	 CAOS® system Sinusurg®, Dental Lab®, Vascular Access Virtual Reality Simulator®, insightArthroVR®, CathLabVR®, Endoscopy AccuTouch®, LapVR®, etc..
Augmented Reality Microscopes	Neurosurgery	product	Leica DI C500®, etc..
Augmented Reality Head Mounted Displays	Laparoscopy	research	Liu, D., Jenkins, S. A., & Sanderson, P. M. (2009). Clinical Implementation of a Head-Mounted Display of Patient Vital Signs. 2009 International Symposium on Wearable Computers (pp. 47-54).
Auto-stereoscopic systems	Cardiac and vascular surgery	research	Ruijters, D., & Zinger, S. (n.d.). IGLANCE: TRANSMISSION TO MEDICAL HIGH DEFINITION AUTOSTEREOSCOPIC DISPLAYS Philips Healthcare, Cardio / Vascular Innovation , Best, the Netherlands Eindhoven University of Technology, Video Coding and Architectures, Eindhoven , the Netherlands, 2-5.

Volumetric displays	Cardiac surgery	research	Wang, A. S., Kao, D., & Liang, D. (2005). An evaluation of using real-time volumetric display of 3D ultrasound data for intracardiac catheter manipulation tasks. Fourth International Workshop on Volume Graphics, 2005. (pp. 41-45)

5. Executive summary

As was concluded in Del. 6.2.1, inside the typical workflow of IGIT surgical procedures several requirements have to be considered (mainly sterility, occupation of the hands with different tasks and distance to screens).
The analisys conducted about the available UI concepts shows that there are several technologies that can be introduced or extended in the IGIT area.
For example:

- Voice and gesture controls can be integrated in IGIT operating room in order to minimize the sterility related issues of touch based medical devices. Issues to be considered are the noise (for the voice control) and ergonomics/robustness limitations (for the gesture control).
- Haptic interfaces are more suitable for the applications in which accuracy is needed (for example surgical robotics) or training.
- Multitouch device are available for a use even in the OR but the issue of sterilization has to be taken in account. I-pad and tablet PC can potentially substitute conventional PC.
- Eye tracking provides low effort, and low focus lost, but hardware limitations for mobility of the user have to be considered.
- 3D displays very are very good to guide interaction, but produce dizziness after long period of used.
- Volumetric displays still in reseach stage with big limitations in hardware-environment compatibility.
- Augmented reality appears to be very promising and useful if it is applied to a simple UI or existing medical optical device (microscopes, endoscopes, etc.).
- In the Control Room standard interface should be extended with advanced visualization technology to explore, filter and manage complex data.

The introduction of innovative user interfaces in the medical workflow need a new complex effort for the integration of different technologies and a study of the compatibility with the medical environment (see paragraph 2.1).
Task 6.2 of Mediate project will use this report (togheter with the requirements at table side in Del.6.2.1) to identify the novel UIs suitable to be introduced in the IGIT workflow.

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