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Related items

Action fidelity
Teleoperation / telepresence / telesymbiosis
Transparency_1
Transparency_3

Transparency_3

Marco Fontana [PERCRO]

Contributors: Massimo Bergamasco [PERCRO], Annie Luciani [ACROE&INPG]

The property of transparency appears once direct manipulations of physical objects, i.e. objects that are in the same space that the person who manipulate them, with or without mechanical tools, have been mediated by added tool components when the manipulated object becomes more and more distant from the space of the user. This situation needed when objects (resp. humans) are dangerous for humans (resp. objects), when there are physically distant, when they are not at the same scale, etc. In such situations, one can say that the so-distant object is teleoperated. In teleoperation, two spaces have to be distinguished: the space of the user on which the user is manipulating a master device and the space of the task on which the object is manipulated by a slave device. The teleoperation chain, i.e. all the components between the space of the user and the space of the task when they are different, was originally only mechanical (through tools extension such as pentographs, etc…). It Progressively, it included electrical mediation and its correlated components sensors and actuators, and more recently digital components and computers.

In such context, transparency is a property of the mediation system. Transparency, i.e. transparency of the added teleoperation components, is perfectly achieved if the operator cannot distinguish between manoeuvring the master device and manoeuvring the actual tool.

In teleoperated robotics, lot of works, technical and theoretical have been performed, and are currently performed, on transparency [Laurence et al., 1996]. It is impossible to obtain perfect transparency. For example this would require an infinite stiffness of the mechanical components. Transparency depends on a wide number of features or parameters of the chain. First of all, transparency in teleoperation is strongly affected by the communication time delay between master and slave [Stanney, 1999].

The ability of a teleoperation system to provide transparency depends also largely on the performance of the master device. Ideally, the master device should be able to emulate any environment encountered by the tool, from free-space to infinitely stiff obstacles. Its performance depends on its electromechanical design and the algorithms used to control it. It depends also both to its dynamic and static properties.

We may observe that, from the point of view of the user, the master device is actually a haptic device. Without considering the properties of the rest of the chain (transmissions and slave devices) in a teleoperation chain and the properties of the simulated world in a virtual reality situation, some properties of the master – haptic – device can be common to both situations. The two main carachteristics are (see also, [→ Stability]):

- Bandwidth, i.e. he frequency range over which the device is capable of exerting forces Dynamic friction. It is the force that has to be exerted in order to maintain a constant low velocity of the haptic device.
- Stiffness [Ueberle et al., 2004], i.e. the maximum achievable stiffness of the manipulated object (virtual or teleoperated) that a haptic device is able to restitute. This depends on the mechanical compliance and the stiffness of the controller.

Actually, there is a common agreement to consider that a perfect transparency is not needed. The scope of an interface is to interact with a human user so the ideal interface is the one that achieves the perfect perceptual transparency. For example the maximum stiffness of a perfect perceptual transparent device has to be greater than the maximum perceivable stiffness by a human operator. In technical terms, this means that the impedance that is displayed by the device can slightly differs from the commanded one but their difference must be not perceivable by the user.

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Related items

Feedback
Force
Haptics, haptic devices
Haptics, in cognitive sciences
Stability

Turing machine

John Stewart [COSTECH]

The Turing machine is a theoretical concept, of basic importance for modern computer science and, by extension, for the computational theory of mind in computer science. This "machine" was invented, in its basic principle, by the British mathematician Alan Turing in the 1930s in order to provide an operational definition of calculability (or decidability) in the context of formal symbol systems [→ Formal symbol systems]. A Turing machine has two components, a tape and a reading/writing head. The tape consists of a potentially unlimited number of discrete positions arranged in a linear sequence. Each position contains a single symbol; it can be shown that without loss of generality, 3 symbols are sufficient (e.g. 0, 1 and Blank). The head, at any given step in the operations, will be in one of a finite number of states, and it will be situated on one of the positions on the tape. The head also contains a matrix, in which the rows correspond to the symbol written on the current position on the tape; and the columns to the current state of the head. Each element in the matrix contains three items of information :

- The new symbol to be overwritten on the current position on the tape (this can be the same as the symbol already present).
- The next position of the head (without loss of generality, this can be reduced to just three possibilities, i.e. one step to the left, one step to the right, or staying on the current position).
- The next state of the head.

An important point is that a "mother" Turing machine can simulate another Turing machine; and in particular, it can be shown theoretically that there are certain Turing machines (defined by the matrix in the head) which can simulate any other Turing machine whatsoever. Intuitively, one makes a separation between the symbols on the tape that are the data on which the calculation is to be performed; and another part of the tape which contains the information of the Turing machine to be simulated. The mother machine stores the information concerning its current state and the symbol on the current position by way of special states devoted to such storage; it then moves to the part of the tape containing information on the "daughter" machine to be simulated, and looks up what the daughter machine would have done in this condition; it stores this information

and returns to the current position to carry out the appropriate actions. Turing machines of this sort which can simulate any other Turing machines whatsoever are called universal Turing machines.

An extremely powerful concept in the theory of formal symbol systems is that of formal equivalence: two such systems are formally equivalent if but only if, for each legal operation in one system, there is one and only one legal operation in the other system, and vice versa (i.e. complete isomorphism). Formal symbol systems that are formally equivalent can vary not only in their material instanciation, but also in their syntax. However, from a theoretical point of view, these variations are totally insignificant. As far as is known, no actual Turing machine (with a physical tape and physical head) has ever been built; the reason is that since other machines (in particular, computers as we know them now) are formally equivalent to universal Turing machines, there is just no point in building an actual Turing machine.

In other words, a Turing machine does not refer to any actual physical machine. It is an abstract, theoretical concept, but an extremely powerful one which is at the basis of the actual computers that have been built. In cognitive science, the computational theory of mind postulates that the brain is a formal equivalent of a universal Turing machine.

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Related items

Algorithm
Computational paradigm
Enactive cognitive sciences_1
Formal symbol systems

U

USABILITY

Haakon Faste [PERCRO]

There are several definitions of usability. The most simple and general is: "*The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" - ISO 9241, Part 11.

This definition is particularly general because it refers to all human computer interfaces (software and hardware). It includes in particular enactive interfaces. Therefore an enactive interface is usable when the following three factors are optimized:

- Effectiveness: accuracy and completeness of the obtained results or of the performed tasks.
- Efficiency: the resources expended in relation to the effectiveness.
- (User) Satisfaction: the comfort and acceptability of the work system to its users and other people affected by its use.

Nielsen employs usefulness as an umbrella term for utility and usability [Nielsen, 1994].

- Utility is the question of whether the functionality of the system in principle can do what is needed.
- Usability is the question of how well users can use that functionality.
- Usefulness is the issue of whether the system can be used to achieve some desired goal.

In Nielsen's definition, usability is the sum of several factors: learnability, efficiency of use, memorability, few and non-catastrophic errors, and subjective satisfaction.

Particularly with regards to user satisfaction, these factors point towards an understanding of usability implying not only that the interface is effective and efficient, but also that it is useful. While usefulness is not a requirement of usability, is an integral concern for all interfaces and makes their use useworthy. The usability of an interface is given purpose if the interface addresses a latent underlying human need. The process of identifying needs is known as needfinding and is an important aspect of user centred design and design research [Faste, 1988] [Patnaik & Becker, 1999]. Designers with empathy for end users' needs not only insure the long-term usefulness of a product's design, they are also more well equipped to address usability issues through their work [Moggridge, 2006] [Brenda Laurel et al., 2003].

Usable systems have affordances causing the user to respond to features of objects and environments intuitively [Norman, 1990]. Thus usability also hinges on physical and perceived design aspects of the interface itself, including its intuitiveness, ergonomics, multimodal feedback, and the ability to personalize, customize, and understand the interaction paradigm. To this end, the use of control/command metaphors in robotics and control [→ CONTROL METAPHORS] can be useful, in addition to interaction paradigms learned over time. In designing usable Enactive Interfaces, important considerations include, in addition to useworthiness, the system's encumbrance and approachability, clarity of the control mechanism, latency, range of movement, and degree of interactivity of the interface. Effectiveness, efficiency, and enjoyability of the system can be measured based on user response.

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Related items

Believability_ 1&2
Control metaphors
Design for all (inclusive design)
Design process
Design, user centred
Interface design
Presence, in computerized environments
Useworthy technology

Useworthy technology

Charlotte Magnusson [ULUND]
Håkan Eftring [ULUND]

Useworthiness is a concept that has been introduced by Håkan Eftring in his PhD dissertation [Eftring , 1999].

The purpose of the concept of useworthiness is to focus on the importance of a product in the user's life situation, thereby gaining increased knowledge of the needs of the user. The focus of the related concept of usability [Nielsen, 1994] [Lindgaard, 1994] [Löwgren, 1993] is more focused on the user interface, i.e. the ease and efficiency with which a product can be used, and to some extent on the functionality and versatility of the product, i.e. the tasks for which the product can be used. Knowledge of the needs of users with disabilities can be used not only for establishing user requirements and developing more useworthy robots, but also for developing other technical tools, as well as for rehabilitation purposes Another purpose of the concept of useworthiness is to give the user the initiative and the power. No-one else can determine what is worth using for the person concerned. This may seem like a disadvantage if one wants to develop useworthy technology. However, by gathering experience of what different people find worth using it is possible to form a general idea of what many people who have similar interests and impairments, who are of the same age, etc. find worth using, and to develop technology to suit their requirements. In each specific situation, one must always engage in a discussion to determine the needs of the individual user. In this connection, the concept of useworthiness is a way of prioritizing all the useful tasks an artefact can be used for.

Nielsen [Nielsen 1994] employs usefulness as an umbrella term for utility and usability. In Nielsen's conceptual framework:

- Utility is the question of whether the functionality of the system in principle can do what is needed.
- Usability is the question of how well users can use that functionality, how easy it is to learn how to use the robot, how efficient the robot is once the user knows how to use it, how easy it is to remember how to use it after a period of not using it, how often minor or catastrophic errors occur, and how pleasant it is to use.
- Usefulness is the issue of whether the system can be used to achieve some desired goal. Thus, usefulness is a combination of utility and usability, i.e. whether the robot can be used for its intended purpose. Can the user turn pages in the way that was intended?

Lindgaard [Lindgaard, 1994] also makes also a distinction between usability and utility:

- "*Usability is related to human performance in the specific tasks supported by the computer system and to the user's attitude towards the system.* […] *Usability is thus expressed non quantifiable, measurable terms by which to assess when a 'good' system is 'good enough'*".

- "*Usefulness...*" corresponds to Nielsen's concept of utility and "*... is a separate entity which is defined in the requirements capture stage in terms of the tasks to be supported and explicit links between tasks, the attainment of which must be 100% unless renegotiated and modified during the system development process*".

An ISO standard provides another definition of usability (ISO 9241). In this standard, usability is defined as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use, in which:

- Effectiveness is defined as: measures of the accuracy and completeness of goals achieved.
- Efficiency is defined as: measures of the accuracy and completeness of goals accomplished relative to the resources (e.g. time, human effort) used to achieve the specific goals.

Using Nielsen's definition of usability as a starting-point, Håkan Eftring [Eftring 1999] introduced the concept of useworthiness as a combination of utility, usability, and the user's high-priority needs.

The same product may have high useworthiness but low usability, which is the case if the utility of the product is low and the user interface is unsatisfactory but the product meets one of the user's high-priority needs. The product may be useworthy even though it is never used. The user knows that the product is capable of performing a task that is important to him or her, but for practical reasons, not necessarily connected to the product, it is impossible for the user to use the product. On the other hand, just because a product is used, it is not necessarily worth using. The user may be forced to use it or may have no other alternative, or the product may not meet the user's high-priority needs. The user's motivation when it comes to using the system is an important component of the concept of useworthiness. A high degree of correspondence between possibilities and needs leads to high motivation and a desire to use the system. When the user sees new possibilities and finds his motivation, his way of thinking may change. Ingrained patterns and subconscious limits to what is possible may be broken, and the user may become more active and grow as a person.

To conclude, useworthiness is a concept that moves focus from the technology to the users - usability can be said to be a system property, while useworthiness is clearly something that a human decides. Thus it is a useful concept to consider in user centred design processes, and generally when designing enactive systems intended to be considered worth using by the users.

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Related items

Design and enaction
Design for all (inclusive design)
Design, user centred
Design process
Interface design
Usability
Design, virtual mock-up
Believability_ 1&2
Presence, in computerized environments

V

VIRTUAL REALITY AND VIRTUAL ENVIRONMENT

Annie Luciani [ACROE&INPG]

Contributors: Pierre Davy [UNIGE], Bart Kevelham [UNIGE], Ronan Boulic [EPFL], Emilio Sanchez [CEIT]

These two terms are usually considered as being synonymous, and are equally used when speaking about a world that is totally recreated by computer simulation. They indeed present similarities, but they also differ in their history, in the contexts in which they are used, and finally in the concepts they are carrying.

The term virtual reality has been coined in 1988 by Jaron Lanier [Lanier, 1988]. However, the same concept has developed under the name of artificial reality, coined by Myron Kruger in 1977 [Krueger, 1977] [Krueger, 1983], who claimed the paternity of the concept. In addition, in 1987, before the Lanier's virtual reality, the term artificial reality had been used by James Foley [Foley, 1987], a renowned researcher in Computer Graphics. The expressions virtual environment and virtual world appeared later.

Indeed, in all these expressions, the term virtual relates to the same concept: "computed by numbers, as opposed to created by physical matter". Virtual reality, virtual environment, virtual words, etc.: they all require computers equipped by computer simulation processes and transducers that transform the digital representations into a perceptible experience (visual, acoustical, mechanical).

However Virtual reality, virtual environment, virtual words, etc. can be differentiated by the position of the human in the respective cases: the immersive position or vis-à-vis position [→ IMMERSION VS. VIS-À-VIS].

Virtual Reality and Virtual Environment: immersive situation

The Krueger's and Lanier's approaches are indeed similar. Both emphasize the immersive approach, in the continuity of the meaning of virtual reality initiated by the data glove, data suit and head-mounted display, that were designed as means of completely isolating the user from the real world and putting him within a completely virtual world. Lanier writes: "*virtual reality uses the approach of designing clothing devices, 'computer clothing', which is worn directly over the sense organs. The objective is to instrument this in such a way that you can provide exactly the stimulus to the person's sense organs that they would receive if they were in an alternate reality*". [Lanier, 1988]. This meaning of virtual reality is synonymous to the meaning of virtual environments, in the sense of worlds surrounding the user and being explored by him. Here, the user is here totally immersed in a virtual (i.e. non real) world. In these uses, the interactivity with the Virtual space involves usually the whole human body, large spatial and visual spaces and 3D sound rendering. A Virtual Environment may faithfully recreate an existing real environment or can be completely fictional [Cadoz, 1994] [Milgram et al., 94]. Correlated questions are, at least: co-location problem [→ CO-LOCATION], graphical representations of humans [→ AVATAR], whole human body motion capture [→ MOTION CONTROL, HIGH-LEVEL], real-time adaptive visual rendering, etc. Classical applications are those involving large spatial space exploration and navigation, but also "*as experimental platform to study the aliened and altered states of the consciousness,* …" [Reingold, 1991].

Virtual reality, artificial reality: vis-à-vis situation

Following the Sutherland's approach that grounds the concept of interactive computer graphics, [Sutherland, 1963], and before, and conversely, to Lanier, J. Foley adopted the

vis-à-vis point of view, and introduced force feedback devices in computer graphics [Foley, 1987]. The Foley's meaning refers to an instrument-in-hand approach. Here, the virtual world is in front of the users. Users are acting, manipulating and transforming the objects of the virtual world, instead of being immersed in it. Also, usually, the interactivity involves rarely the whole body, but focuses on hand and arm manipulation. These virtual realities implemented first hand interactivity and visual feedback. They progressively include, more and more, several sensors, haptic devices, 3D models, physics and dynamics, sound synthesis, hence becoming more and more multisensorial and enactive. Basic correlated questions are, at least: accuracy of the manipulation, accuracy of the visual representation of objects, collision process optimization, dynamics of objects, precision of force feedback [→ Force feedback], cooperation between geometrical models and physical models, etc.

Some remarks

As a first remark, whatever the meaning chosen, one should also note that virtual reality and virtual environment computerized systems are often components to augmented reality systems and to mixed reality systems [→ Reality, augmented and mixed].

As a second, remark, one can notice that the way of categorisation we propose here, based on the distinction between on the one hand virtual environment / immersion and on the other hand virtual reality / vis-à-vis, which allows understanding the differences between these quite-similar terms, is perfectly compatible with the enactive concept: the categorisation is grounded by the type of relation between the humans and the external world.

Going further: reducing the gap

The most important challenges of the future interactive systems is to develop adaptive systems able to merge these two approaches in order to create really virtual worlds in which humans could evolve from an environment point of view when exploring spaces to a vis-à-vis point of view when manipulating objects. The merging, however, is nothing but difficult [→ Immersion vs. vis-à-vis].

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Related items

Avatar
Co-location
Computer graphics
Force feedback
Haptics, haptic devices
Instrumental interaction
Immersion vs. vis-à-vis
Motion control, high-level
Reality, augmented and mixed

VIRTUAL REALITY THERAPY

Helena Grillon [EPFL]
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Virtual Reality Therapy (VRT) or Virtual Reality Exposure Therapy (VRET) is a method of psychotherapy that uses virtual reality technology to treat patients with anxiety disorders, Post Traumatic Stress Disorder (PTSD), and several other medical phobias. It is a therapeutical approach that can overcome some difficulties inherent to traditional treatments. It can provide the needed stimuli for a patient having difficulties imagining the feared situation. Moreover, it can be used in privacy and can be tuned to patients' needs. This allows to avoid embarrassment and violation of patient confidentiality and allows the possibility to stop the exposure at any time should the patient suffer from a panic attack. The first research for VRT was done in the early 1990s [North et al., 1997].

The use of virtual reality therapy to combat phobias was introduced in the 1990's by Barbara O. Rothbaum and Larry F. Hodges for treating fear of heights, fear of flying, fear of public speaking and PTSD in Vietnam war veterans [Hodges et al., 1995] [Klinger, 2005].

Many studies have been conducted regarding the use of virtual reality in therapy:

- Regarding psychological disorders, the use of virtual reality in the treatment of acrophobia, addictions, aero-acrophobia, agoraphobia, arachnophobia, claustrophobia, developmental learning disorders, driving phobia, eating disorders, fear of public speaking, male sexual disorders, OCD (Obsessive Compulsive Disorders), PTSD (Post-Traumatic Stress Disorders), and social phobia has been studied [Klinger, 2005].
- Other studies have been led in the field of distraction from pain [Hoffman, 2004].

Some anxiety provoking scenarios are difficult to access and are not easily available in real life. As an example, it would be extremely difficult for a therapist to fill his/her office with spiders in order to treat a patient. The main aim of VRET is to present an alternative to standard in vivo exposures when these are difficult to reproduce.

When it comes to enactivity, the aim is not for the patient to directly influence the scenes to which he/she is exposed, since this requires the therapist's judgment. However, the therapist is able to choose the degree of anxiety to which the patient is exposed. Even more, based on the feedback produced by patient, the therapist can adjust and modulate the virtual reality program for the exposures to be fully adapted to the patients' needs. As an example, for a patient who fears crowded areas, he will first be exposed to a scene depicting a small crowd of maybe 20 people. Once the patient is able to deal with this small crowd and the therapist considers that his anxiety has fallen below a certain threshold (by using physiological measures for example, such as heart rate or skin conductance), the degree of exposure will be increased. The patient will then be exposed to a crowd of maybe 50 people. This cycle will be repeated until the patient is able to deal with real life situations.

A higher degree of enactivity can be achieved by using the physiological measures and the patient's visual contact behaviour to automatically tune the scene to which he is exposed. However this is not without risks, so the therapist's expertise will always remain essential to assert the patient experience and adapt the experience in fine.

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Related items

Design for all (inclusive design)
Intelligent characters
Learning and training methods
Virtual reality and virtual environment

Visual perception

Manfred Nüsseck [MPIT]

The visual system, part of the nervous system, lets organisms receive, collect and interpret visible stimuli of (reflected) light with different wavelengths. For developing human-computer interfaces or applications, which focus on believability and simulation of reality, it is most important to know the basic operating modes of the human visual system. There are a lot of traps [→ Illusions, visual] as well as helpful findings of vision research, which should be taken into account for perceptual and technological studies of enactive interfaces.

Generally, the eye receives light and turns it into neural impulses that are analyzed and interpreted by several separated areas of the visual cortex, which are specialized in different aspects of vision. The physiological approach on visual perception focuses directly on the nervous system and the visual cortex and tries to detect the rules of the process of how patterns of light, falling on the receptors on the retina, are transformed by neural networks into patterns of electrical activity [Hubel, 1989] [Bruce et al., 2003].

A different approach turns away from the physiological level and concentrates on how it is possible that light-signals reaching a perceiver give rise to perceptual experiences and visually guided actions [Bruce et al., 2003] [Goldstein, 2006]. This field can be divided into several different theories of visual perception.

One important theory is the computational approach to visual perception. It formulates models of interpretation of information to be existent in retina images first invented by Marr. Vision is seen as an (computer) operation in which a set of symbolic descriptions of the retinal image is converted into a symbolic shape-oriented representation [Marr, 1982]. The visual system does this by analyzing mathematically how certain intensities in the images change, co-calculating so called natural constraints (similar to the regularities of the Gestalt theory). Marr's work-in-progress influenced later the so called feature integration theory [Treisman, 1998].

Another important approach emphasizes and investigates the information itself available in extended spatial and temporal patterns in the optical array. It situates the human in an action-perception-loop and tries to describe the reciprocal process of how perceived information influences the movement of an observer and its movements influence in return following percepts. This ecological theory, invented by Gibson [Gibson, 19799, takes not the retinal image as the starting point, but the ambient optical array, which an observer actively samples. Gibson maintains that optic flow and disturbances in the structure of the total optic array provide information cues for the perceptual impression, rather then computable symbols.

To avoid perceptual misinterpretations and to clarify communication about it, this knowledge is important for developing believable enactive interfaces and applications.

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Related items

Auditory perception
Display, visual
Classification of perceptual modalities
Computer graphics
Constructivism
Illusions, visual
Virtual reality and virtual environment

Z

Zoomable experience

Mounia Ziat [COSTECH]

Contributors: Armen Khatchatourov [COSTECH], John Stewart [COSTECH]

The zoom as a form of human experience appeared historically with the invention of optical instruments. Developmentally, it also requires learning in order to become an integral part of human perception. This zoomable perception is enactive, in the sense that it only through action that the subject brings forth a knowledge and a meaning of this world of varying scales. Directly inspired from cinematographic zoom, zoomable user interfaces [→ Zoomable interfaces] can provide the affordance [→ Affordances] of locomotion, in the sense that subjects can experience multi-scale navigation as a foreshortening of distances that enable them to approach the object of perception. By inventing these instruments of enlargement, human beings have instrumented their eyes and increased their perceptual capabilities to scrutinize on one hand the microscopically tiny and on the other the confines of the universe. There is a biological precedent, i.e. the eye of the eagle which, thanks to a specialized anatomy, confers a magnifying glass effect when observing the ground during flight.

There are several types of zooming techniques [→ Zoomable interfaces]. The originality of the semantic zoom (compared to a bitmap or geometrical zoom) is that it provides a feed-back on the magnification factor, because each element of semantic content is associated with a certain level in the scale. As concerns the nature of the subjective experience of the user – is it the object which increases in size, or does the user approach the object? – the semantic zoom is interesting because both types of experience can occur. When the subject zooms on an object, several levels of zoom are performed before the qualitative change in semantic content occurs, i.e. during this phase the object does not change its appearance. This phase is experienced as an enlargement of the size of the object. When the semantic content changes, however, the subject is conscious of perceiving more details and thus has the impression of moving closer to the object in the dimension of depth. Thus, the navigation occurs in two steps : an initial navigation without depth, and then a navigation with depth which is experienced as an extension of the body on the axis of scales. In other words, if depth is experienced on the axis of scales, then the subject has the experience of approaching the object. Conversely, if depth is not experienced, the subject has the impression that the object is expanding.

In the case where access to depth is achieved, a zoomable user interface simulates the affordance of locomotion, since the subject has the impression of approaching the object (or that the object is approaching the observer). On the other hand, the classical mode of zoom does not give the impression of navigating in depth and therefore does not afford displacement.

From the point of view of the optical array [→ Array, global], this is translated by a symmetrical radial flow in the case of a classical zoom (Guiard et al., 2005); but by an asymmetrical radial flow in the case of a semantic zoom or a 3D zoom. These two types of flow "*have in common that they specify a progression in the position of the observer with respect to the document. […] These flows thus both give information on displacements that are directly usable. However, only the second (asymmetrical) flow carries prospective information*".

To sum up, there are two distinct types of zoomable experience : the enlarging zoom and the approaching zoom. The enlarging zoom is essentially a 2D zoom which, directly inspired by a magnifying glass, makes it

possible to increase or to decrease the dimensions of an image (digital zoom, cinema zoom, magnifying glass). The approaching zoom is a 3D zoom that makes it possible to visually bring the objects nearer or further (optical zoom, travelling, microscope / telescope). Zoomable user interfaces can be considered as 2D½ objects (Perlin and Fox, 1993).

Another criterion that intervenes with zoomable interfaces is the concept of reversible occlusion. As introduced by Gibson, it rests on the fact that a surface hidden by another surface can be revealed to an observer in movement, and conversely some parts of a previously visible surface can be occluded when the observer reverses the trajectory. For Gibson, all locomotion is essentially reversible, so that any surface occluded by one direction of locomotion will be revealed again by the reverse movement (Gibson, 1979). In terms of the optical array, one speaks of projected surfaces to designate visible surfaces. Conversely, hidden surfaces have no solid angle in the ambiant optical array and so they are said to be non-projected in the array.

Just as in the real world, in a zoomable virtual world objects tend to occlude each other. An object that exists at a certain level of zoom is occluded by a semantically different object at a different level of zoom. This can be an advantage in the sense that the information is distributed over different levels of zoom; but it has the disadvantage of the *desert fog* phenomenon (Jul et Furnas, 1998), i.e. the empty space within which the user can lose himself after a certain time spent in navigating at several different scales. After several successive levels of zoom, it is necessary to apply a reversible occlusion so as to find again the information present on the context page. Thus, with a zoomable interface, the transfer to a virtual world of the principle of reversible occlusion is successful since it is sufficient to return on one's tracks to recover the contextual information. This is made possible by the affordance of movement in depth.

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Related items

Affordances
Array, global
Externalization, perceptual
Zoom, haptic
Zoomable interfaces

Zoomable interfaces

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The appearance of personal computers has opened to theirs users general purpose tasks such as word processing, Internet browsing, multimedia playback, computer game play, etc. If all these tasks benefit of computer hardware evolution (power, memory, etc.), the display possibilities and interaction means remain the same since twenty years (Beaudouin-Lafon, 2004). The field of information visualization plays an important and crucial role for visual representation possibilities because it considers limits and possibilities of the human perception and the display support. One of the interfaces created in the field of information visualization are zoomable user interfaces (ZUI) which give an efficient and promising mean of interaction to represent and manipulate great quantity of information. The principle of navigation

inside zoomable user interfaces is based on the space-scale diagrams developed by Furnas and Bederson (1995). The objects containing the information are organized in the spatial dimension but also in the scale dimension. In order to access the information, the user interacts directly with the information space using mainly pans and zooms. By contrast with the classic zoom or bitmap zoom (see below), which is discrete, the zoom employed in ZUI, is a continuous geometrical zoom (see below) which gives the user a feel of flying through a space. In addition to the continuous zoom, the graphic content of the information changes at each level by the technique of semantic zoom (see below). The main improvement brought about by zoomable interfaces is a reduction in the amount of information that is displayed at any one point in time. This reduction alleviates the cognitive overload during navigation in a large data-base, because the principle underlying these interfaces is much more intuitive. These interfaces do however require an amplification of the database itself which must contain a number of different, hierarchically structured representations of the object.

Below we present the different types of zoom.

Bitmap zoom

A bitmap zoom consists of performing an enlargement of a pixellized bitmap image. The zoom is carried out directly on the pixels, so that the zoom corresponds to a change in resolution. The bitmap zoom is discrete (the unit is the pixel) and its range of variation is limited (it is bounded in both directions). Thus: at the lowest level of zoom, the whole image is reduced to a single pixel. In the other direction, the more the size of the pixels is increased, the resolution is reduced. In some software applications, when the image is enlarged additional pixels are created; but even this inevitably leads to a blurring of the image. This type of zoom is used in Paint software for MS Windows, Adobe Photoshop.

Geometrical zoom

When a zoom is performed on a vectorial image, the curves which compose the image are automatically recalculated for the rescaled image. Thus, contrary to the bitmap image where the objects are composed of pixels, a vectorial image is composed of points, lines and mathematical curves. For example, a straight line is defined solely by the co-ordinates of the two extreme points. A circle is defined solely by the co-ordinates of its centre and its radius. Thus, all the transformations involved in rescaling the image change only these mathematical values and do not alter the quality of the curves. The main advantage of a geometrical zoom is that it does not suffer from the phenomenon of pixelization when all or part of the image is zoomed. With a bitmap image composed of discrete points (pixels), when a forward zoom (magnification) is performed, the pixels become clearly visible (this phenomenon is familiar to users of software such as Paint). By contrast, in vectorial mode, all the components of the image are mathematical curves which are not intrinsically pixelized. When performing a forward zoom, the computer recalculates all the curves so as to adapt them to the required scale. This geometrical zoom is unlimited since whatever the scale, the contours are perfect and the images appear clean. This type of zoom is used in software for vectorial drawing as Corel Draw, Adobe Illustrator.

Semantic zoom

The semantic zoom is an articulation between the geometrical zoom, which makes it possible to provide greater detail, and the logical zoom which provides more information. Goldstein & Roth (1994) define access to a certain level of detail as follows: the user changes the granularity of the data which are the focus of attention. Since Goldstein & Roth use this definition to describe hierarchically structured data, this definition can also be used to give an account of the technique of semantic zoom. In other words, a seman-

tic zoom is just a modification in the structure of data which are organized hierarchically and presented at different levels of granularity. By contrast with an ordinary zoom where the object has just a single representation with different degrees of resolution, the object in the environment of a semantic zoom has a number of different representations in the database of the interface. The idea of using a semantic zoom as the basis for interaction has been proposed by Perlin & Fox (1993) with the Pad interface, as an alternative to the WIMP paradigm. In Pad, a hierarchy is created where at the lowest level the object resembles a legend or a title, and at the highest level the object is a (part of) the complete document. This technique has been taken up by Frank & Timpf (1994): in order to render this intelligent zoom operational, use a hierarchical tree-structure to display representations of geographical maps at different scales. Thus, the semantic zoom changes the form and the context in which the information is presented. For example, the display of a digital clock can differ according to the scale. In an initial median view, the clock displays the time of day and the date. If the user performs a forward zoom, the form of the clock changes and displays the minutes and seconds. With a backward zoom, the time of day disappears and only the date and year are displayed (Stephens 2003). The advantage of the semantic zoom is that it avoids the use of deformed views such as the Fisheye (Leung and Apperley, 1994). This advantage is linked to the use of a semantic transition between the general view and the detailed view (Modjeska, 1997). This type of zoom is used in zoomable user interfaces.

The use of the type zoom depends on the task. For example, it is more judicious to use bitmap zoom to modify pictures because one works on pixels, but it is more recommended to use geometrical or semantic zoom when one works on the display of a great amount of data. New techniques of interaction, as ZUI have the advantage to be more intuitive and natural. A couple of ZUI examples are provided in the Related Document field.

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Related items

Computer graphics
Interface
Metaphors in human-computer interaction
Zoom, haptic
Zoomable experience

Related documents

The following internet pages provide example of zoomable user interfaces.
www.cs.umd.edu/hcil/piccolo/
maps.google.com/
www.infres.enst.fr/net/zomit/zomit-net/more.html

Zoom, haptic

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A zoomable experience [→ Zoomable experience] is generally considered as visual. However, the use of sensory substitution

devices [→ SENSORY SUBSTITUTION SYSTEMS] give us the possibility to experience in a given perceptual modality what is usually experienced in another.

In general, a zoom corresponds to a change in the resolution of an object. This can be represented as a window of constant size moving on a vertical axis of scales (Furnas and Bederson, 1995). If the object becomes small relative to the window, this corresponds to moving away; if the object becomes large relative to the window, this corresponds to a movement towards the object. It is the relation between the size of the image and the size of the window which defines the level of zoom; this can be expressed by the formula z = I/F, where z is the level of zoom, I the size of the object, and F the size of the window.

On the basis of this formula, we can examine the situation when the size of the image remains constant, but the size of the window changes. In this case, when the size of the window F increases, the level of zoom decreases; when the size of the window decreases, the level of zoom increases. Technically, this situation is functionally equivalent to the classic zoom.

The principle used for visual zoom can be used for haptic modality. Here we provide an example of use of the haptic zoom with a sensory substitution device named Tactos (Lenay et al., 2007). This device allows the display of 2D graphical objects by mean of the haptic modality. Tactos makes it possible to explore 2D graphical objects by moving a stylus on a graphic tablet. These displacements of the stylus command the displacement of a the virtual window (or the matrix of receptor field) on the computer screen, and which give rise to a tactile stimulus (namely a dynamic pattern on Braille cells) if the receptor field encounters a 2D object on the screen. This window moving on the screen can be compared to a virtual screen that moves over fixed numerical objects. By changing the size of this window, we can obtain the resolution and precision required. In haptic zoom, the change of he side of the window (i.e. receptive field) result in a different tactile pattern on Braille cells.

Thus, the smaller the size of the window/receptor field, the higher the resolution; the larger the size of the window, the lower the resolution and the (virtual) zoom. Technically, this corresponds to a change of scale. To obtain full functional equivalence with the classical form of zoom where it is the size of the object which changes, the movements of the stylus (and hence the movements of the receptive field on the computer screen) must be scaled down in strict proportion to the size of the window.

Different experimental situations have been implemented with this interface in order to define factors which encourage a zoomable perception through the haptic modality (for more details, see Ziat et al., 2007). On one hand, these experiments helped us to better understand the constitution of a zoomable perception. A zoomable perception corresponds to an alternation of expansion and depth, when it is visual; and to either a real displacement on a surface or the displacement of an object relatively to another, when it is haptic.

On the other hand, they reinforce the idea that a prosthetic perception is submitted to the same laws than the others perceptual modalities. Perception by means of prosthesis is a new perceptual experience which can be constructed in the same way as the natural perceptual modalites.

To sum up, if the zoom is a perceptual experience often conceived as visual, it is possible to constitute this perception with haptic modality, notwithstanding the fact that the tactile is not favourable to the depth perception [→ HAPTIC DEPTH PERCEPTION] in the real world (this sense requests the contact with the object).

In other words, the depth experience can be the subject of a true substitution within the framework of the interaction of the subjects with virtual objects.

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Related items

Haptic depth perception
Haptic form perception
Sensory substitution systems
Tactile device
Tactile rendering
Zoomable experience
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Institutions Websites

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