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FROM VIRTUALITY TO REALITY AND BACK

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ABSTRACT:

There has been a growing research interest in investigating techniques to combine real and virtual spaces. A variety of “reality” concepts such as Virtual Reality and Augmented Reality and their supporting technologies have emerged in the field of design to adopt the task of replacing or merging our physical world with the virtual world. The different realities can be tailored to enhance comprehension for specific design activities along a design life-cycle. This paper presents state-of-the-art applications of these “reality” concepts in design and related areas, and proposes a classification of these realities to address suitability issues for the effective utilization of the concepts and technologies. Their potentials and implications in certain design activities are also discussed.

1. INTRODUCTION

The recent emergence of visualization techniques has ushered in new opportunities for enhancing design and planning functions in the architecture, engineering, and construction (AEC) industries (Griffs and Sturts 2000). More specifically, over the past decade, there has been a growing research interest in investigating techniques to combine real and virtual spaces (Anders 2003). A variety of “reality” concepts (Virtual Reality, Mixed Reality, Augmented Reality, Augmented Virtuality, Mediated Reality, Diminished Reality, Amplified Reality, and Virtualized Reality) and their supporting technologies have emerged in computing and design areas to take on the task of replacing or merging our physical world with the virtual world. The shared philosophy behind these concepts is to bring the virtual world of computers into the physical world of everyday human activity. Often the differences between these concepts of reality are not clearly identified and their attributes are vaguely defined. This is due to the nature of reality being an inherent concept of existence and derivations are only possible through technological enhancements. Subsequently, some realities overlap with one another in both concept and implementation. Nonetheless, different realities can be tailored to enhance design comprehension and collaboration for specific activities along a design life cycle (Kvan 2000). A thorough observation of the mostly lab-based prototype applications in multiple domains highlights the need for a classification to address suitability issues for the effective adoption of those realities and technologies. Such classification can be used to maximize the benefits of these reality technologies for certain design activities and reveal their implications in design.

The first part of this paper presents an application survey of these reality technologies with insights supported by close review of the related application cases. The classification in the latter part of the paper can assist designers in comparing alternative technologies and developing an effective system according to characteristics of the design activities.

2. REALITIES CONCEPTS AND THEIR APPLICATIONS

The design industry opens the door for further innovations in these “realities”. The increasing number of applications from these “realities” demands relatively official definitions to classify them. Compiling terminology for the “realities” serves to ameliorate discussion of design implications, as well as identifying a way of classifying existing applications. This section presents an overview of reality technologies. It was revealed that the subtleness of differences between some “reality” concepts was likely to create confusion (Milgram and Colquhoun 1999); thereby making it necessary to elucidate the fact that different “realities” can be tailored to enhance design comprehension and collaboration for specific life cycle activities.

2. 1. VIRTUAL REALITY

Virtual Reality (VR) visualization technology, which creates a total Virtual Environment (VE), was originally embraced by architecture visionaries for design concept presentations during the recent decades. As computing has advanced, they have supported more sophisticated graphics capabilities (Hendrickson and Rehak 1993). VR research attracts a considerably wide range of interest in diverse fields, with the typical application being web-based design review, computer-supported cooperative work (CSCW), as well as 3D-type thinking with desktop-PC and headset-based VEs. In 2001, for the first time, immersive VEs were successfully employed to create and communicate architectural design in a larger context (Schnabel 2002). In VEs, subtle human-to-human interaction is locked in these environments, which often provide only limited support for the physical expression of emotion and personality. The notions of VRs are relatively familiar compared with other concepts, and have been widely applied in many areas of design and research. This paper will thus focus on other modes of reality.

2. 2. MIXED REALITY

Mixed Reality (Milgram and Colquhoun 1999), a more expansive form of VR, describes a concept where computer-generated content and the real world intermingle. It offers new potential for interaction between design information and collaborators for the entire life cycle of the engineered facility. Depending on the method of augmentation, Mixed Reality involves two major modes: Augmented Reality (AR) and Augmented Virtuality, which will be discussed in the two subsections that follow. Mixed Reality has been applied to enhance design practices. For instance, Wang, Shin and Dunston (2003) developed an intuitive mixed environment called Mixed Reality-based Collaborative Virtual Environment (MRCVE) to support collaboration and design spatial comprehension in collaborative design review sessions for mechanical contracting. The environment supported both face-to-face and distributed communication. A slightly different interpretation of Mixed Reality is presented in Schnabel et al. (2004) where a cyclical design process that interchanged between real and virtual realms in order to develop and communicate architectural design resulted in a crossing over between the various realities. Designs were created by moving from one realm to the next by cycling from the real, over to augmented and virtual environments, enabling designers to mix the realities as they saw fit. Another system named MIXDesign (Dias, Santos and Diniz 2002) provided a Mixed Reality system that reframed various steps of an architectural design task creating a fluid translation of the design within the various realms.

2. 3. AUGMENTED REALITY

Creative collaboration demands separation from the context of the physical real world. As a sub-mode of Mixed Reality based on the definitions by Milgram and Colquhoun (1999), AR can add virtual elements into the physical real world, which can be associated with tangible interfaces and provide great benefits in architecture and urban design (Seichter and Schnabel 2005). Though real elements in AR could potentially place certain constraints on the shared imagination, major advantages of AR include ease of collaboration, intuitive interaction, integration of digital information, and mobile computing.

AR allows a user to work in a real world environment while visually receiving additional computer-generated or modelled information to support the task at hand. In the past, AR environments have been applied primarily in scientific visualization and gaming entertainment. In recent years, it has been explored for goal-oriented human activities like surgery, training and collaborative work. One of the applications of AR in the early phases of a design is sketching, which is a rapid and fuzzy embodiment of the architectural discussion. The sketchand+ system (Seichter 2003) is an experimental prototype that makes a first attempt to use AR in the early stages of architectural design and was found to have a potential impact on the quality of the design-process. The prototype system can assist in creating and editing sketches, preserving the naturalness of the traditional way of sketching. BenchWorks (Seichter 2004), the next generation of sketchand+, was developed as an AR prototype for analyzing representational design in an urban design scale, which focused on techniques and devices needed to create 3D models for urban design. Another example of tabletop AR systems for urban planning is the ARTHUR project (Broll et al. 2004), in which optical see-through AR displays were used together with decision support, software for architectural, and urban design. Dunston and Wang (2005) developed an AR system called Augmented Reality Computer Aided Drawing (AR CAD) for individual mechanical design detailing. Yabuki, Machinaka and Li (2006) applied the AR technology in the erection of steel girder bridges by employing ARToolkit, later developing a simple prototype for checking interference between the steel girders and the surrounding buildings in order to ensure accurate erection of the bridges. Another example is BUILD-IT (Rauterberg et al. 1997), which is a multi-user planning tool using a 2D projection on a table top.

The state-of-the-art in AR today is comparable to the early years of VR in that many systems have been demonstrated but few have matured beyond laboratory-based prototypes. More practical application domains of AR technology can be found in a thorough survey by Azuma (1997). Some technological problems like low resolution video capture devices and low resolution head-mounted displays have prevented the wide spread adoption of AR in various fields of applications including design.

2. 4. AUGMENTED VIRTUALITY

With interpersonal imaginative interaction, Augmented Virtuality (AV), the augmentation of a virtual setting with real objects provides a means to merge a richly layered, multi-modal, 3D real experience into a VE (Milgram and Colquhoun 1999). Design industry paves the road for more innovations in Augmented Virtuality (Oxman 2000), a more expansive form of VR. Despite its potential, Augmented Virtuality has not received as much attention as VR and AR. AV has only been applied in very limited domains: as displays on unmanned air vehicles (Rackliffe 2005), 3D video-conferencing systems (Regenbrecht et al. 2004), and a scientific centre (Clarke, Vines and Mark 2003). Recognized research effort towards AV applications in the design domain is fairly limited.

2. 5. MEDIATED REALITY

Mediated Reality refers to a more general framework for artificial modification of human perception by way of devices that augment (Starner et al. 1997), deliberately diminish, and more generally, alter sensory input. This is typically achieved by altering a video input stream light that would normally directly reach the user's eyes, and computationally filtering it into a more useful form. Mediated Reality has been proved to be advantageous in deliberately diminishing the perception of reality, which gives way to another “reality” concept: Diminished Reality. Diminished Reality removes an object or collection of objects which are then replaced with an appropriate background image (Lepetit and Berger 2001). It creates special effects to assist urban planners in visualizing a resulting landscape where a building is proposed, removed, or replaced from the original landscape. Mediated Reality applications, such as those introduced by Bandyopadhyay, Raskar and Fuchs (2001), are found in architecture via changing building appearance, sketching modifications, industry (through the addition of colour/material to a scale mock-up), art (through visual assistance during realization of a sculpture), and also in rapid prototyping or packaging design) by adding, for example, photometric properties to the model).

2. 6. AMPLIFIED REALITY

To amplify reality is to enhance the perceivable properties of a physical object, by means of using embedded computational resources. Amplified Reality (Falk, Redström and Björk. 1999) was originally introduced as a concept complementary to that of AR. Compared with AR, which enhances impressions of real objects, Amplified Reality amplifies the expressions of objects in the real world and emphasizes the importance of the shared experiences that result from publicly available properties of objects. AR is about how the user perceives reality, while amplified reality is based on how the perceived might control how information is made available. Amplified reality has been applied in the projects of the Lovegety (Iwatani 1998), the Hummingbird (Holmquist, Falk and Wigström 1999) and the BubbleBadge (Falk and Björk 1997).

An amplified object is self-contained in regard to its properties. In practice, this means that the properties are embedded parts of the object. In contrast, AR superimposes virtual properties on an object, which in effect does not change the actual object, but rather how we perceive or experience it. The important difference between these two approaches lies in the proprietary rights to the information. An amplified object controls the flow of information, while in an AR system the perceiver is in control of the information. In other words, an AR system alters the impression of its user, without there being any corresponding properties in the expression of the object the user is perceiving (Falk, Redström and Björk 1999).

2. 7. VIRTUALIZED REALITY

Virtualized Reality virtualizes real-world scenes by capturing scene descriptions - the 3D structure of the scene being aligned with its image - from a number of transcription angles (Kanade, Narayanan and Rander 1995). The scene can then be synthesized from any viewpoint using one or more scene descriptions. To generate data for such a medium, the event needs to be recorded using many cameras, which are positioned so as to cover the event from all sides. The time-varying 3D structure of the event, described in terms of the depth of each point and aligned with the pixels of the image, is computed for a few of the camera angles, called transcription angles, using a stereo method. The collection of a number of scene descriptions, each from a different transcription angle, is called the virtualized world. Once the real world has been virtualized, graphics techniques can then render the event from any viewpoint. Wearing a stereo-viewing system, the viewer is able to freely move about in the world and observe it from a viewpoint chosen dynamically at view time (Kanade, Narayanan and Rander 1995).

Stereo or image-matching methods, which are the key components in Virtualized Reality, are well-studied as presented by Kanade, Narayanan and Rander (1995). Precise reconstruction of the entire scene using a large number of cameras is, however, relatively new. Kanade (1991) proposed the use of multi-camera stereo using supercomputers for creating 3D models to enrich the virtual world. Rioux, Godin and Blais (1992) outlined a procedure to communicate complete 3D information about an object using depth and reflectance. Fuchs and Neuman (1993) presented a proposal to achieve tele-presence for medical applications.

2. 7. FROM REALITY TO VIRTUALITY

We presented in the above sections definitions and applications of realities that ranged from Reality, over Mixed Realities to Virtuality. Milgram and Colquhoun (1999) presented a definition of Mixed Realities within the context of a Reality to Virtuality continuum (Fig.1). This classification does not include the fine differences of the above discussed realities.

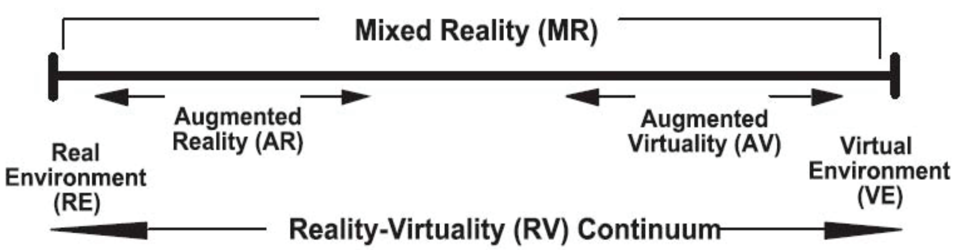

Figure 1: Order of reality concepts ranging from Reality (left) to Virtuality (right)

Figure 2 presents an overview of the various realities with their degree of reality, where reality is on the left side of the spectrum and virtuality on the right.

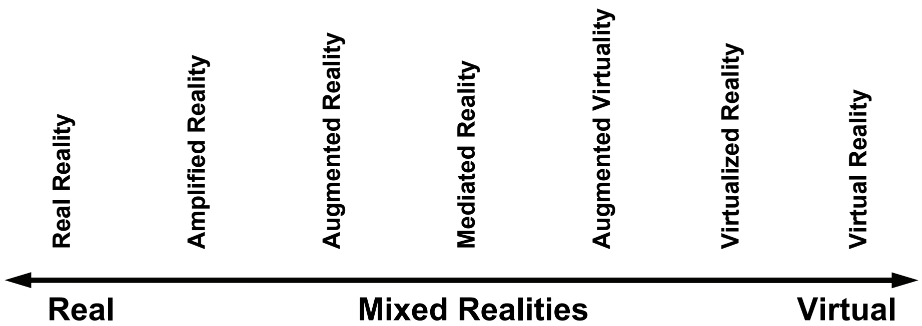

Figure 2: Order of reality concepts ranging from Reality (left) to Virtuality (right)

3. CLASSIFICATION OF REALITY TECHNOLOGIES

The focus of this section is the proposition of a structured classification of the identified reality concepts and technologies. This classification summarizes the main differences between these reality concepts according to two dimensions or attributes, and is applicable to the design of a system supported by reality technologies based within the constraints imposed by different design activities. It also allows for comparison between reality realms and technologies. There are two areas, which we shall refer to as 'dimensions', that relate either to a correlation of action or to a perception and the level of interaction with physical artefacts, tools, and surroundings.

3. 1. FIRST DIMENSION: CORRELATION OF ACTION AND PERCEPTION

Aicher (1994) criticizes the lack of "doing" by planners and the overemphasis on the reduction of real-life to inner, rational activity. He advocates a closer connection between action and mental reflection, indicating a need to enable users to bring together action and reflection in human-computer interaction. In the context of design, this means to create possibilities for the users to try out the design tool through use, not only through reflection (Bødker 1991). Hence, people must be able to employ their everyday motor faculties in their interaction with design tools such as computing devices. A further important aspect of the design philosophy is the correlation between action and perception space (Rauterberg 1995). When handling physical objects, the space in which we act coincides with the space from which we receive (visual) feedback: we can see what we do. This is not the case for virtual object handling with a mouse-keyboard-screen interface, where there is an apparent separation between action and perception spaces. The research by Hacker and Clauss (1976) further confirmed this by finding that performance increases when task-relevant information is offered in the same space where action takes place. According to Aicher (1994), the perception and action are defined as follows:

Perceived scene. The final image perceived by the user can be modified. The 2D spatial reference depends mainly on the display technology, be it optical overlay, video composition, or light projection.

Action on objects. Modifying properties of a real object. Of particular interest are geometry and appearance, which can be modified on a global or local level with respect to the object.

3. 2. SECOND DIMENSION: EXTENT OF INTERACTION WITH REAL ENTITIES

This second dimension rests on Bødker's (1991) and Kaptelinin's (1996) work, where they apply activity theory to human-computer interaction. Before we began to develop a framework, we studied users' need by employing task analysis methodology. Fundamental to modern activity theory is the idea that the development of thoughts and cognitive activity requires social interaction and exchange with a physical environment. Handling ever more abstract objects and concepts is part of an individual's cognitive development. Nevertheless, the physical environment remains important, since it is used for the externalization of thoughts and as external memory. The modified artefacts in the physical environments can be real objects. Within this context, the level of interaction with real artefacts refers to the degree at which the designers/users are allowed to impose modifications onto the real artefacts that are directly or indirectly involved in the design activities.

3. 3. CLASSIFICATION ACCORDING TO THE TWO DIMENSIONS

Figure 3 provides a high-level overview of the classification of those reality concepts and technologies according to the two dimensions: correlation between perception and action and level of interaction with real artefacts. The six major realities can be positioned on this classification. Real/physical reality (e.g., blackboards, physical meeting tables, etc.) combine both the local and physical.

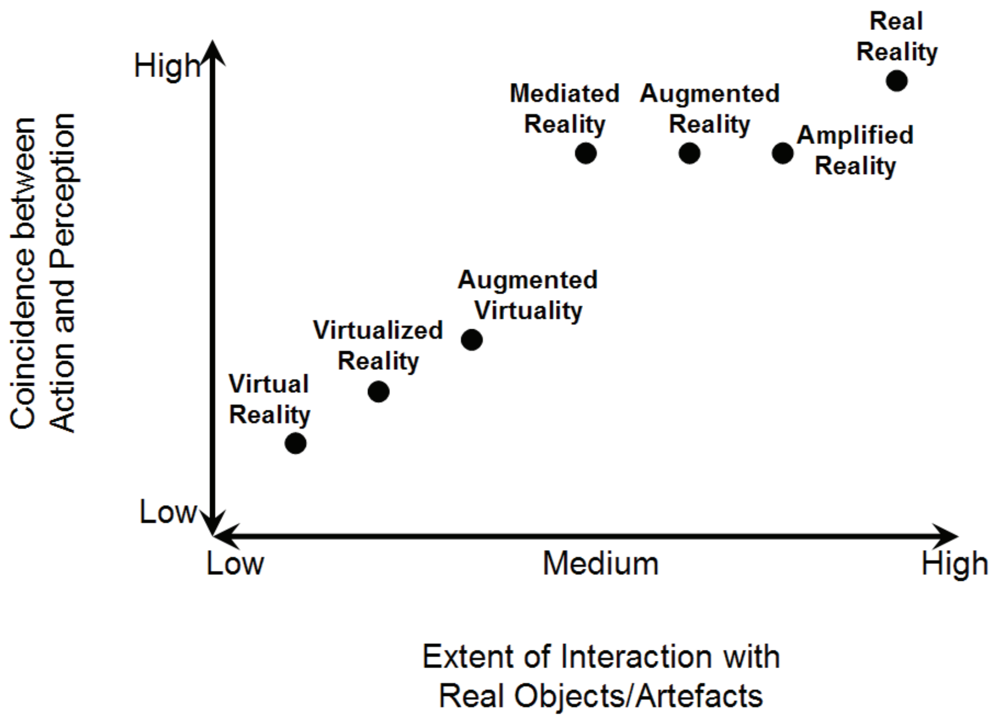

Figure 3: Classification of reality concepts according to correlation between perception and action and level of interaction

As we can see from Figure 3, Amplified Reality, most closely to real reality, involves higher interaction with Reality as compared with AR. For instance, suppose you want a new colour on the walls of your room. Usually, this is achieved by painting them in the preferred colour, but this result might also be achieved by wearing a pair of coloured eyeglasses that make the wall appear differently. Essentially, the coloured glass in the spectacles adds an additional layer of information on top of the real world, and in this way augments it. Now, re-painting the walls would correspond to amplified reality, resulting in a direct interaction with the real environment and artefacts. Wearing the eyeglasses in AR involves no interaction/change of the real environment/artefacts (Falk, Redström and Björk 1999). Therefore, an AR system alters the impressions of its user, and amplified reality changes the attributes of the real objects. By embedding publicly available properties in amplified reality, the information distributed will be controlled by the perceived object itself. This is likely to become important when considering communication between humans, as integrity in a large part has to do with what others "know" about oneself. Mediated Reality involves an even lower level of interactions with real artefacts compared with the above two realities, because the real counterparts (objects) in mediated reality are actually replaced/diminished by the imposed virtual counterparts (objects). Thus, relatively fewer real contexts to interact with are left available.

A common feature among these three realities is that they all share a similar level of correlation between action and perception, because by their technology definition, the virtual objects are actually visually aligned with their real counterparts. Therefore, the perceived space which is usually determined by virtual objects is correspondent to the action space which typically consists of the real artefacts. The principle of coincident perception and action space is subsumed under these three realities. For instance, AR is based on real objects, augmented by computer-based, intelligent characteristics. AR recognizes that people are used to the real world, which cannot be authentically reproduced by a computer.

These three realities might be suitable for planning activities, because of the higher correlation between action and perception. These three realities typically include aspects of natural communication which serve as mediators for mutual understanding: eye contact, body language, and physical object handling. They also respect body-space. At the same time, users can still draw on the advantages of a virtually enriched world, which is of particular importance to planning tasks. The activity of planning is mainly 'virtual' because it involves reflecting on and modifying objects that will only exist in the future. Virtual models of these objects can be more easily changed than real models. They can be stored in external computer memory and can be visualized for interaction purposes. Thus, both real and virtual models have their rightful place in a planning process. Planning tasks require all (or several) members of a workgroup to mutually transfer their individual knowledge, expertise, and experience into a material form. Planning tasks require even more mutual exchange of knowledge among experts (Lauche, Verbeck and Weber 1999). It is easy to apply those systems onto artefacts and tools, resulting in sketches, documents, and three-dimensional (3D) objects or devices. Hacker, Sachse and Schroda (1998) describes the importance of grasping design ideas by sketching and low-cost prototyping. These methodologies within concepts of reality will potentially help achieve design results in a faster and better way than by using abstract design processes and more detailed methods such as VR. For instance, bricks (Fitzmaurice, Ishii and Buxton 1995) can be seen as physical devices for exteriorization in a planning process.

Mediated Reality may also be employed within a conceptual design realm that places a focus on "sketching results" (modifying appearance). For instance, interactive mediated reality systems can enable a user to paint, grab, or glue both real and virtual objects, and can be conceived of as an authoring tool. Different methods and solutions can be used such that reality can be modified. The most interesting system for modifying the appearance of real objects is Raskar's work on shader lamps (Bandyopadhyay, Raskar and Fuchs 2001). Based on a projection approach, he realized a prototype for painting on real objects, and also provided the illusion of animation of real static objects. New possibilities such as painting on ordinary objects can be introduced by adding 3D material, real-time texture acquisition from video, and a technique to avoid occlusion.

Compared with VR, Virtualized Reality involves a larger level of interaction with real artefacts because users can change the viewpoint to a virtualized event/scene by changing the positions and layout of the cameras, which can be regarded as a type of artefact in a real surrounding. The level of correlation between perception and action is higher than VR, where viewers are able to move in a virtual world where the perceived scene is isolated from the real artefacts (action space). Their worlds are usually artificially created using simplistic CAD models and set viewpoints virtually. Virtualized Reality, in contrast, starts with a real world and virtualizes it, maintaining a relatively higher correlation of perception and action. Apparently, the two dimensions of these two realities are lower than in Mediated Reality, AR, Amplified Reality and Actual Reality. Virtualized Reality can be an entirely new generation of design medium: architects and landscape designers can be given the feeling of sitting and watching from their preferred seat in a proposed basketball stadium to perceive the lighting, perspective, or safety issue. This is especially suitable for a design review of a final product model and walkthrough.

4. SUMMARY

This paper presented state-of-the-art applications of various “reality” concepts in the area of design and related fields. They ranged from Reality to various forms of Mixed Realities (Amplified-, Augmented-, Mediated-Reality, Augmented Virtuality, and Virtualized-Reality) and to Virtual Reality. We discussed a proposition of a structured classification to address suitability issues for the effective adoption of these realities and technologies, realities which are often tailored to enhance design comprehension and collaboration for specific activities. The proposed classification can assist designers in comparing alternative technologies and developing an effective system according to characteristics of the design activities. This allows a definition of the terms and their appropriate use in design. The potentials and the subsequent implications of these realities allow an academic discussion and exploration of design activities and contribute to the general understanding and communication of these realms in design.

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