THE REAL IN AUGMENTED REALITY

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What is augmented in Augmented Reality (AR)? This fundamental question has received surprisingly little attention in AR research. In this paper, we review existing views and show how little consensus there is on the topic. Subsequently, we approach the question from a theoretical and technology-independent perspective that focuses on the relationships between the virtual and the real. We consider both spatial as well as content-based augmentations and distinguish between augmented environments, augmented objects, augmented humans, augmented content and augmented perception. We discuss our findings and suggest possible future directions, such as research into multimodal and crossmodal AR.

1. INTRODUCTION

In Augmented Reality (AR), virtual and real content are combined in a real, physical environment. AR has been emerging as an academic field since the late 1990s. So far, research has mainly focused on technologies and techniques that enable or support the integration of virtual visual objects in our view of the real physical world, such as tracking or calibration techniques (cf. Zhou, Duh, and Billinghurst 2008). We, however, propose to interpret AR as a more general concept that potentially includes all modalities and not necessarily requires advanced computational technologies.

In this paper, we explore the conceptual characteristics and possibilities of AR. We ask "What is augmented in Augmented Reality?" and "What forms of augmentation do exist?". This paper addresses these questions from a creative, theoretical and technology-independent perspective. We approach augmentation by looking at the relationships between virtual and real elements. We distinguish between augmentations that are based on a spatial relationship between the virtual and real and augmentations where the virtual and the real are related content-wise. The paper illustrates how such spatial and content-based relationships can result in augmented environments, augmented objects, augmented humans and augmented content.

Our research is driven by our personal interest in better understanding the qualities and potential manifestations of AR. We are especially interested in non-visual (for instance, sound-based) and multimodal forms of AR. Our work aims to provide a theoretical foundation and foster reflection, experimentation, artworks and exchange rather than final results.

The paper is divided into four sections. Section 2 gives a short overview of existing views on the topic. Subsequently (3), we present our own understanding of augmentation and consider augmented environments, augmented objects, augmented humans, augmented content and augmented perception. We conclude the paper (4) with a discussion of our findings and suggestions for future research.

2. WHAT IS AUGMENTED IN AR?

The term itself – Augmented Reality – indicates that reality is augmented. Hugues, Fuchs and Nannipieri (2011, 2)

have argued the impossibility of this suggestion: "If reality is by definition everything that exists, then strictly speaking reality cannot be augmented since it is already everything. So what is augmented?"

In existing AR literature, we can find different views on the matter. Many argue that it is not reality but the *perception* of reality that is augmented. For example, Normand *et al*. (2012, 1) point out: "Reality can not be increased but its perceptions can. We will however keep the term 'Augmented Reality' even if we understand it as an 'increased perception of reality'." Similarly, Ross (2005, 32) refers to AR as that "what should be called augmented perception of time and space." Also the widespread survey of AR by Azuma (1997, 3) claims that AR enhances a user's perception of and interaction with the real world. Hugues, Fuchs and Nannipieri (2011) have explicitly addressed the question as part of their AR taxonomy and distinguish between AR environments that augment the perception of reality and environments that aim at immersing users in an artificial environment.

Furthermore, there is the notion that in AR, our *real physical environment* is augmented. This has for example been stated by Milgram and Kishino (1994, 1322): "As an operational definition of Augmented Reality, we take the term to refer to any case in which an otherwise real environment is 'augmented' by means of virtual (computer graphic) objects [...]". (Unfortunately, the authors are not completely consistent and also refer to the augmentation of the *display* of an otherwise real environment.)

Besides the idea of an augmented environment, we also find the notion of augmented *space*. The media theorist Manovich (2006) introduces this more general concept and describes it as "physical space overlaid with dynamically changing information, multimedia in form and localized for each user" (p. 219). Manovich lists AR as one of the technologies, that already create such augmented spaces.

Looking at Wikipedia's current definition of AR ("Augmented reality"), we again find a different opinion on what is augmented in AR. As of April 15, 2014, AR is described as "a live, copy, view of a physical, real-world environment whose *elements* are augmented [...]" (italics added by the authors).

Yet another approach is suggested by Mackay (1996). The author considers the carrier of the physical equip-

ment as augmented (e.g., the user is augmented when he/she carries a helmet and an object is augmented when sensors are embedded in it) and consequently distinguishes between an augmentation of the *user*, an augmentation of the *physical object* and an augmentation of the *environment* surrounding the user/object.

Considering popular views on AR, such as Milgram *et al.*'s (1994) Reality-Virtuality continuum[1] and Azuma's (1997) widespread survey on AR,[2] we can identify general agreement among researchers that in AR, virtual content is overlaid, projected onto, or otherwise added to (our perception of) a real environment. However, as the reviewed literature illustrates, there is little consensus on what is actually augmented by this virtual content. We think this has two main reasons: Firstly, there has been little said about what constitutes augmentation in an AR context. Secondly, there is not one right answer to this question.

In our previous research, we have proposed an understanding of AR that can shed light on the problem (Schraffenberger and van der Heide 2013). We consider AR the result of the relationships between the virtual and the real. As a preliminary answer, we claim that the augmentation does not necessarily have a target. Rather, there is a real component and a virtual component to the augmentation. Their relationship constitutes the augmentation.[3] Unfortunately, this view is conflicting with the language associated with AR. Even the term "Augmented Reality" implies that something (Reality) is augmented.

We believe that there are two different forms of augmentation, corresponding to two different forms of relationships between the virtual and the real. The relationship can be either spatial (as is the case when virtual objects are integrated into a real 3D environment) and/or content-based (as is for example the case when AR applications present us with information about a specific place or object).[4]

We propose to replace the question "What is augmented in AR?" with the questions "To what does the virtual content relate?; What is the real component in the augmentation?; What is the real in AR?". In lack of better alternatives, we will continue using the already accepted terms and language.

1 The Reality-Virtuality continuum describes environments where real objects and virtual objects are presented together within a single display. It ranges from purely virtual environments to entirely real environments. AR is placed within this continuum and describes an otherwise real environment that is augmented by virtual objects.

2 In this survey, Azuma (1997, 2) summarizes AR as a field that "allows the user to see the real world, with virtual objects superimposed upon or composited with the real world."

3 If we look at an AR scenario, we usually perceive both the virtual and real at the same time – relating, complementing and adding to each other. It hence appears just as accurate to claim that the real augments the virtual as to claim that the virtual augments the real.

4 Various other relationships between the virtual and real (e.g., interaction between virtual and real objects) are possible (Schraffenberger and van der Heide 2013). However, we believe that all of them are based on underlying spatial or content-based relationships.

3. THE REAL IN AR

In the following, we group, illustrate and extend the ideas collected in section 2 and discuss them in the context of our proposed understanding of augmentation. We consider augmented environments, augmented objects, augmented humans, augmented content and augmented perception.

3.1. AUGMENTED ENVIRONMENTS/SPACE

In an augmented environment, there is a relationship between virtual content and its real surroundings. As pointed out, this relationship can be spatial and/or content-based. A spatial relationship is common in cases where virtual visual objects are integrated in a real 3D space. When, for example, a virtual chair is added to a real desk (cf. Azuma 1997) there is a spatial relationship between the real environment and the virtual chair: the chair is part of/integrated in the real space.

Content-based relationships between the environments and virtual content are also common. For example, the mobile app *Layar* (*http://www.layar.com*) shows site-specific information such as nearby restaurants, metro stops and ATMs and overlays this data onto the real world using a mobile phone's screen.

It is important to note that the virtual content does not have to be presented visually. We can find various examples of sound-based augmented environments: Cilia Erens' sound walks are designed for a certain walking route and mainly use unprocessed binaural recordings of everyday-sounds (Erens; cf. Schraffenberger and van der Heide 2013).[5] When the participant navigates the environment and listens to the composition on headphones, the recorded sounds merge with the sounds present in the existing environment and invite the participant to make connections between the added sound and the existing environment.

Another example of an audio-based augmented environment is Edwin van der Heide's (2000-) *Radioscape* (van der Heide 2000-; Schraffenberger and van der Heide 2013). The installation makes use of multiple radio transmitters that are distributed over a part of a city, each transmitting one layer of a meta-composition. By navigating through the city with a custom-made receiver (see Fig. 1), a listener can pick up several signals at a time. The volume of the single layers depends on one's distance to the corre-

5 See, for instance, *Hollands Doorzicht* (2006), *http://www.cilia-erens.nl/portfolio-2/hollands-doorzicht-berlijn-2006/*. This sound walk is made of sounds that were recorded in the Netherlands and took place close to the Dutch embassy in Berlin, 2006.

sponding transmitters. For the participant, there is a clear relation between the content and environment. What one hears depends on one's own location, the position/placement of the transmitters and the shape of the city. Small movements of the receiver lead to repeatable changes that happen in the space around the listener. Besides experiencing the city in a new way, the participant discovers and experiences the relationships between sound and space.

Fig. 1 A participant is experiencing *Radioscape* as part of the Electromagnetic Bodies exhibition in Rotterdam, 2006. Image courtesy Studio Edwin van der Heide.

It is crucial that linking virtual content to specific locations alone isn't enough to result in the experience of a spatial augmentation. This can be concluded from *Wormhole Dordrecht*, another concept by Edwin van der Heide, which was realized in 2008. For this project, ten artists were invited to each make a sound environment existing of multiple sound files, linked with GPS coordinates to locations in the center of the city Dordrecht. The Wormhole environment was experienced with a custom developed iPhone application, which used GPS coordinates to start, stop, fade and mix the sound files. In *Radioscape*, the surrounding buildings work as resonators and reflectors for the transmitted radio waves, resulting in detailed changes that relate to the environment. However, in *Wormhole* the individual sounds are only linked to GPS coordinates and there is no further influence between the sounds and the spatial environments within the city. Although the resulting soundscapes depended on the participant's position in the city and although it was

clear that sound files were triggered and mixed depending on the listener's location, there was no experienced tangible relation to the physical space. This, however, does not mean that there was no augmentation. An augmentation could also take place on a content level (for instance, when narratives relate to the space) and thereby still result in an AR experience.

3.2. AUGMENTED OBJECTS

The fact that virtual content *exists* in a real environment does not necessarily mean that the virtual content also *relates* to this environment. There are cases where the virtual relates to, or becomes part of, a particular physical element/object. This is, for example, the case in the context of projection mapping. Here digital images are projected on physical models. One example of an augmented object is the augmented zebrafish by Gómez-Maureira *et al*. (2014). In this project, the zebrafish's skin is projected on a physical bigger-than-life zebrafish (see Fig. 2). The audience can look inside the fish and reveal additional information (for instance, an X-ray visualization and a basic anatomical schematic) by stepping in front of the projector and moving their shadow over the fish's surface. This is realized using a kinect sensor, which detects the shadows, and a secondary projector that fills in the shadows with the additional content. Here the virtual content primarily relates to (and becomes part of) the fish, rather than to the general surrounding space. Both components - the virtual and the real - are designed in a way that deliberately leaves out certain characteristics. These 'missing' aspects are filled in by the other component, resulting in one hybrid virtual-real model (cf. Schraffenberger and van der Heide 2013).

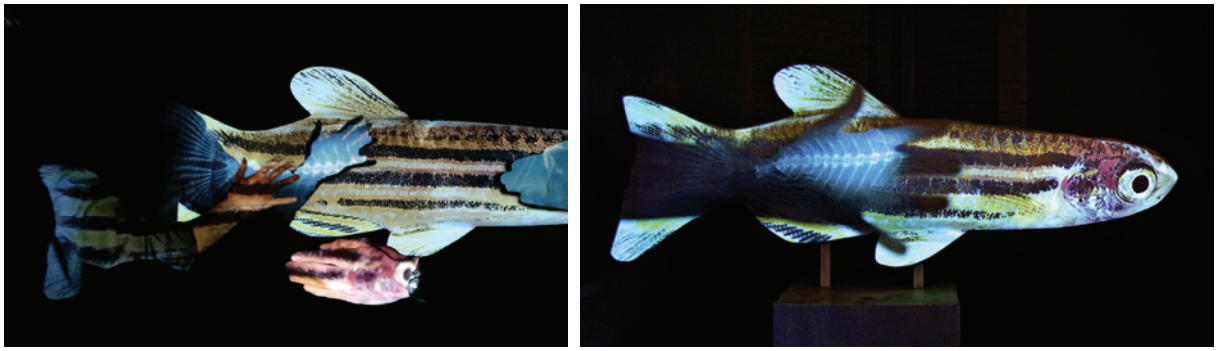


Fig. 2 The augmented zebrafish (length approximately 1,75 m). The fish's skin is projected on a physical model. The shadows of the viewers reveal the inside of the fish (X-ray view).

A distinction between augmented environments and augmented objects is especially relevant when we consider the user or audience. Although viewers are part of the environment, they are usually not part of an augmented object. While environments usually invite the audience to navigate through them, augmented objects might facilitate interaction with the objects. Apart from that, a clear distinction between augmented objects and augmented environments is not always possible.

3.3. AUGMENTED HUMANS

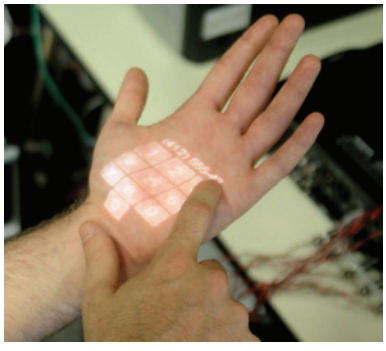
Just like there can be relationships between real objects and virtual content, there can be relationships between humans and the virtual. For example, the art installation *Cloud Mirror* temporarily merges the online identities of visitor's with their physical selves (Gradman 2010). It accesses Internet web services to identify visitors by name and find photographs of and facts (dirt) about them. When visitors approach the digital mirror, the found data is superimposed in an on-screen comic book-like thought bubble that follows the visitor's motion. The virtual content relates to the human both spatially and content-wise.

While in *Cloud Mirror* visitors have no influence on what data is displayed, we can also imagine scenarios where AR allows us to modify our own appearance. An early example of this is the AR-tattoo (Archer 2010) that displays an animated 3D tattoo above a marker, which is physically tattooed onto someone's arm.

A more serious example is the Skinput interface (Harrison, Tan, and Morris 2010). This technology allows the skin to be used as an input surface. In a proof-of-concept, a numeric keypad was projected upon on a user's palm and allowed the user to tap on the palm to dial a phone number (see Fig. 3).

From a technological perspective, augmented humans do not differ much from augmented objects. However, as the human's role changes drastically, it makes sense to treat this as a separate conceptual category.

Fig. 3 Skinput turns the user's palm into an input surface. Image courtesy of Chris Harrison.



3.4. AUGMENTED CONTENT/INFORMATION

We have shown that virtual information/content can relate to the real. Next to this, information/content can also be the real component in the virtual-real relationship. For example, information in a book might be supplemented with interactive 3D illustrations, a soundscape or relating smells. The software *Layar* allows publishers

of print media to add digital content such as links, videos or polls to analogue print content. Another example is The MagicBook project by Billinghurst, Kato and Poupyrev (2001). Here, virtual sceneries pop up when the pages of the children book are viewed through a handheld display.

The augmentation of content is not restricted to visual content. For example, virtual musical improvisers can improvise with real musicians (see, e.g., Walker 1997). In such a case, the behavior of the virtual improviser relates to the present musical content. Although systems like this are certainly no new development, they are usually not considered in the context of AR.

3.5. AUGMENTED PERCEPTION

It has been argued that AR is in fact an augmentation of our perception (Normand *et al*. 2012; Ross 2005; Hugues, Fuchs, and Nannipieri 2011). In our understanding of AR, this is not the case. According to us, the virtual usually does not relate to our perception but to something that is perceived.

Nevertheless, there are forms of AR that arguably extend our perception. AR potentially allows us to perceive things we normally can't perceive. A well-known example, which is usually not seen as AR, is a hand-held Geiger counter, which produces audible clicks that correspond to the amount of radiation (Schraffenberger and van der Heide 2013). It is debatable whether these forms of AR really extend our perception, or only map the unperceivable to our – unchanged – perceptual space. However that may be, the additional information (e.g., the amount of radiation) still relates to the environment/space.

Other projects have aimed at changing the taste of cookies (Narumi *et al*. 2011) by superimposing visuals and adding olfactory content with an AR system. Again, one could argue, that such additions target our perception. However, it should not be forgotten that artificial flavors have been used in this way for a long time, and hence, similarly could be considered AR. As the superimposed content relates to the real food, we consider this to fit in the category 'augmented objects' rather than 'augmented perception'.

4. DISCUSSION AND CONCLUSION

Little consensus exists on what is augmented in AR. We have proposed an alternative approach to this question that focuses on the relationships between the virtual and

the real. Building on this view, we have identified two common forms of augmentation: firstly, cases where the virtual and the real are spatially related and secondly, cases where the relationship is content-based.

We have identified such spatial and content-based relationships between virtual content and the environment, objects, humans and information. We do not claim that we have presented all possibilities. Are there other – non-spatial and non-content-based – forms of augmentation?

By creating spatial relationships between the virtual and the real, we can essentially augment everything that exists in space. So far, AR research and practice has put much emphasize on such spatial relationships. In the future, we can further explore the realm of content-based relationships. Can the virtual relate to thoughts, moods or feelings? What about augmented events, processes and activities?

Much AR is vision-focused and integrates visual virtual content in our view. Strikingly, even in vision-based AR, the virtual can still relate to more than what we see. If, for instance, a virtual visual bird is added to our view of a garden, the bird will relate to the whole environment – a garden we can also touch, smell and hear – not just to the garden we see. Clearly, the real in AR is more than meets the eye.

We have pointed out the possibility of non-visual forms of AR. In this context, we want to pursue research into crossmodal and multimodal AR: When is information of one sensory channel experienced in relation to information of another sensory channel? When do we perceive sounds (e.g., a virtual and invisible bird's twittering) as related to what we see, when do we perceive smells in relation to what we hear? These questions call for an interdisciplinary research approach that incorporates insights from philosophy, perception and AR.

Although we have presented some interesting results, the main contribution of this direction of research is the fact that it brings important questions to the attention of AR research and practice. We are convinced that the AR community will benefit from a theoretical discussion and would like to invite other researches and practitioners to join in on the dialogue about the fundamental characteristics of AR.

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