

# Towards Novel Relationships between the Virtual and the Real in Augmented Reality

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**Abstract.** In Augmented Reality (AR), virtual and real content coexist in the same physical environment. However, in order to create AR, solely adding virtual content to a real space does not suffice. In this paper we argue that an augmentation *adds* and *relates* something virtual to something real. Subsequently, we discuss both existing and promising future relationships between the virtual and the real. We explore what AR is and what it could possibly include from a technology-independent and conceptual point of view. By comparing our take on AR with common manifestations of AR, we identify possible directions for future research and AR (art) works, such as the use of non-visual modalities and the design of novel interactions between the virtual and the real.

**Keywords:** Augmented Reality, Augmentation, Real, Virtual, Media Art, Mixed Reality, Modalities, Multi-Modal, Senses, Interaction.

## 1 Introduction

In Augmented Reality (AR), virtual and real content coexist in a real, physical environment (cf. [1,2]). Something similar happens when we turn on the radio and hear the newsreader speaking. However, the sound of a radio — in combination with the sounds of our surroundings — is generally not experienced as an augmentation of the environment. It is this observation that motivates our research into the nature of AR. Aiming at a better understanding of AR and its potential for media art, we explore what AR is and what it can encompass. We discuss current understandings of AR and explore alternative notions of the paradigm.

Our investigation into the characteristics of AR is driven by our personal interest in better understanding the qualities and potential manifestations of AR (including the artistic ones). We are furthermore interested in the possibilities of addressing other senses, not just the visual. We believe that the conventional definitions of AR are too limiting and we are curious about alternative forms of combining the virtual and the real. Our research intends to foster experiments, artworks, exchange and discussion rather than stating fixed results.

We are interested in the concept of augmenting the real with the virtual; technological aspects of AR fall out of the scope of this paper.

The paper has five sections. Section 1 gives a short introduction. Section 2 defines augmentation and argues that AR requires a relationship between the virtual and the real. Section 3 identifies both existing and promising future relationships. Section 4 discusses our view of augmentation and compares it to existing understandings. Section 5 concludes the paper and points out possible future directions.

## 2 Augmentation

In AR, virtual content is superimposed, overlaid, projected onto or added otherwise to our real environment. As a consequence virtual and real content appear to coexist in the same physical space (cf. [1,2]). This common view is shared and spread by acknowledged AR researchers. Milgram et al. discuss AR in terms of the much-cited Reality-Virtuality continuum [10,11]. The continuum describes the realm of Mixed Reality (MR) environments “in which real world and virtual world objects are presented together within a single display” [10]. The continuum ranges from purely virtual environments to entirely real environments. Augmented reality is placed within this continuum and describes an otherwise real environment that is augmented by virtual objects. Similarly, Azuma’s widespread survey [1, p. 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.”

AR has become an emerging academic field since the late 1990s. It is frequently discussed in the context of technologies and techniques that enable or support the augmentation of the physical world with the virtual, such as tracking or calibration techniques (cf. [16]). Another trend in AR research is the focus on visual augmentations, such as the integration of 3D graphics in the real world (see, e.g., [1,10,11,16]). However, we can also interpret AR as a more general concept of augmenting the real with the virtual.

**Adding  $\neq$  Augmenting.** When interested in augmenting the environment, the common notions of AR can be misleading. One might assume that adding virtual content to the environment augments the environment. However, this is not true in general: virtual content *can* augment the environment, but not necessarily does so.

The example of the radio has illustrated that the presence of virtual content in our environment does not necessarily mean that the environment becomes augmented. Examples for sonic environments where augmentation does take place are Janet Cardiff’s audio walks and Cilia Erens’ sound walks. Cardiff’s walks date back to 1991 and are designed for a certain walking route. While navigating the space, the listener is presented with instructions such as “Go towards the brownish green garbage can. Then there’s a trail off to your right. Take the trail, it’s overgrown a bit. There’s an eaten-out dead tree. Looks like ants” [3]. Besides spoken content, one gets to listen to edited mixes of pre-recorded sounds, which blend in with the already present sounds of the surroundings. The virtual

soundscapes mimic the existing physical one “in order to create a new world as a seamless combination of the two” [3]. Similarly, Cilia Erens, who introduced her sound walks in the Netherlands in 1987, superimposes virtual worlds onto the real one. In contrast to Cardiff, she forgoes spoken content and uses largely unprocessed everyday sounds. Yet, the effect is similar [4]: “a new reality within existing realms, a form of ‘augmented reality’.” Why is that? Unlike with traditional radio, the real and the virtual do not just coexist in the same space but also relate to each other. The pre-recorded sounds used by Erens and Cardiff are designed to mix with the sounds present in the environment. Furthermore, Cardiff’s spoken comments refer to what you see around you and Erens’ work invites you to make connections between the added sound and what you see. In contrast, the sounds played by a traditional radio are generally not related to the environments in which they are played back; they are *independent* content (and are usually experienced that way).<sup>1</sup>

By acknowledging a necessary relationship between the real and the virtual, we can sharpen our understanding of AR. Augmentation is the result of the relationship(s) between the virtual and the real and not just the addition of the virtual.

### 3 Relationships between the Virtual and the Real

Technically speaking, the realization that the virtual and the real have to be related is not new. In 2002, MacIntyre [8, p. 1] writes “The relationships between the physical and virtual worlds is what makes Mixed Reality applications different from other interactive 3D applications.” Looser et al. [7, p. 22] refer to MacIntyre when they point out that “Creating content for Mixed Reality (MR) and specifically Augmented Reality (AR) applications requires the definition of the relationship between real world and virtual world.” Hampshire et al. [5, p. 409] make a similar reference to MacIntyre: “Designing content for MR is driven by the need to define and fuse the relationship between entities in physical world and virtual world.” New media theorist Manovich [9, p. 225] notes: “In contrast [to a typical VR system], a typical AR system adds information that is directly related to the user’s immediate physical space.”

The fact that the relationship between the virtual and real is a defining characteristic of AR applications is clearly acknowledged. However, looking at what relations between the virtual and real are commonly defined, we are surprised: while we can discover manifold relationships in existing AR works and applications, AR research commonly reduces the topic to *registering* real and virtual objects with each other. This is most prominently the case in Azuma et al.’s widespread definition [1,2]. It states that an AR system “combines real and virtual objects in a real environment; runs interactively, and in real time; and registers (aligns) real

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<sup>1</sup> Another difference is that the audio/sound walks invite the listener to navigate the space. While this doubtlessly is an important factor for the experience of the work, it is not required for the augmentation.

and virtual objects with each other” [2, p. 34]. Furthermore, research on AR almost exclusively addresses the relationships between the real and the virtual in a technical context. In the following, we address the topic from a conceptual point of view and explore the various relationships we can find, perceive and imagine.

**Spatial Relationships.** The most dominant manifestation of virtual-real relationships in AR is a *spatial* relationship between virtual and real entities. As virtual objects and real objects are aligned with respect to each other, we perceive the spatial (three-dimensional) relationships between them (e.g., a virtual pen might seem to lay on top of a table and to the left of a glass). Here the virtual objects relate to the surrounding space in the sense that they are *part of/integrated in* the environment.

**Content-Based Relationships.** Typically, the virtual is not only integrated in the environment spatially but also relates to it on the content level. This can be achieved by specifically creating the content with respect to the real or by presenting content that is *already* related to a specific environment, location or object. Common examples are applications that inform us *about* an environment/object or *annotate* it. For instance, information about a painting, building or monument can be presented virtually at that particular site.

**Temporal Relationships.** AR often builds on temporal relationships. For example, images can be presented (e.g., superimposed) at the spot where they were taken years ago or sounds can be played back where they were recorded earlier. Here, AR builds on a relationship between the past and the present.

**Transformation.** A popular approach in site-specific AR is the *modification* of the appearance of real world objects by means of the virtual. Here the virtual seems to *transform* the real. As a consequence, real objects appear differently and gain virtual (often temporary) properties. Although this is not limited to site-specific art, it is especially well known in this context. A whole building can, for example, serve as a canvas for 3D artworks which appear to dynamically transform the underlying architecture in real-time (see, e.g., [14]).

**Translation.** More and more applications of AR do not *simulate* additional objects but aim at *revealing* what usually is unperceivable. A well-known example is a hand-held Geiger counter, which produces audible clicks that correspond to the amount of radiation. Here the relationship between the virtual and the real is a *translation* from something real we cannot perceive to something virtual we can perceive.

**Replacement and Removal.** We are often surrounded by a saturated (visual) environment. Hence it comes as no surprise that AR artists have looked into ways of *removing* things as well. A good example is Julian Oliver's Artvertiser: a mobile augmented reality project that removes advertisements and *replaces* them by art [12].

**Complementation.** We can imagine scenarios, where the virtual *complements* the real and vice versa. For this to happen successfully, often both, the virtual and the real, are specifically designed in a way that leaves out certain aspects in order to be filled in by the other. This happens for example in the field of Augmented Prototyping. Here digital images are projected on physical models, resulting in a mixed virtual-real prototype [15].

**Influence and Interaction.** Developments in AR increasingly focus on interaction between a user and an AR system (cf. [2,16]). However, interaction between a real user and virtual content not necessarily contributes to the augmentation. What we are looking for in AR are relationships between the virtual content and that what it augments.

In line with this, an often neglected aspect is the interaction between the environment and the virtual content. Influences between virtual and real entities can model existing influences, e.g., a real ventilator might move virtual leaves. The need for such behavior has been pointed out by MacIntyre [8, p.3], who suggests using “*physical laws* (i.e. gravity, inertia) when real and virtual *objects interact*.” However, the virtual does not require us to stick to behaviors and reactions that we would expect from real objects. On the contrary, it would be interesting to explore influences and interactions that are impossible to realize between real objects but which are nevertheless believable.

We can take the idea of influence between the virtual and real one step further and imagine bidirectional influences between virtual and real entities. Once the virtual is not only influenced by something real but also influences the real in return, we can speak of true interaction between the virtual and real.

An artwork which demonstrates that real objects can interact with virtual content in novel ways is *Radioscope* by Edwin van der Heide [6]. The installation makes use of several 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 developed receiver, a listener can pick up several signals at a time. The volume of the single layers depends on one’s distance to the corresponding transmitters. Due to the chosen wavelength, buildings become conductors and resonators for the transmitted signals. The physical environment is excited by and responds to the transmitted radio waves, ultimately influencing what one hears.

Also the often-desired interaction between an audience/user and an augmented environment can be realized by establishing influential relationships between physical and virtual objects. Once physical objects influence virtual ones, the audience can interact with the augmented environment, simply by interacting with physical objects.

**Composed Relationships.** With regard to AR art, artists and designers can compose their own, novel, possibly more abstract relationships between virtual content and the environment. It is then up to the audience to discover these.

## 4 Discussion

We have presented a conception of AR that applies to those combinations of the virtual and the real where a relationship between the two exists. Our view of AR differs therefore from widespread understandings of AR. In the following, we compare our notion with existing views.

**The Virtual.** In contrast to generally accepted views such as those introduced by Milgram et al. [10,11] and Azuma et al. [1,2], our definition is more comprehensive with respect to what we consider virtual content. Firstly, it does not limit the virtual to virtual *objects*. Furthermore, we do not require computer-generated or digital content but also accept analog forms of the virtual. Looking at definitions as well as applications, AR is often restricted to the sense of sight (cf. [16]). Opposed to these trends, our definition does not require nor promote visual augmentations of the environment.

**The Real.** Our take on AR is also more encompassing with respect to what can be augmented. We do not limit possible targets of the augmentation to our (visual) environment. In our opinion it is ‘something real’ that gets augmented. This ‘real’ can range from an environment to objects to processes or activities. Consequently, our conception of AR includes participatory works of art in which virtual content is added and related to the behavior of a ‘real audience’. This happens for example in David Rokeby’s *Very Nervous System* [13]: when a participant moves in front of the camera, his or her movement gets augmented with sound. It is interesting to note that spectators of this interaction between the participant and virtual content are confronted with a typical AR scenario: something real (the participant’s actions) is related to/augmented with virtual content.

Just like the virtual is not limited to visual content, we cannot only augment ‘what we see’. For example, Cardiff’s audio walks [3] relate to both, what we see and what we hear.

**Relating the Virtual and the Real.** Compared to common definitions, our notion of AR is less restrictive regarding how the virtual and real can be combined. We require a relationship between the virtual and the real (the virtual can relate to the real, the real can relate to the virtual or they can relate to each other). However, unlike Azuma et al. [1,2], we do not consider the (real-time) registration of virtual and real objects a requirement.

Our main objection to such a definition is that augmentation can be achieved without registration. If we consider non-visual modalities, examples are not far to seek: the above mentioned audio/sound walks [3,4] accomplish an integration of virtual content by mimicking the sonic nature of the surroundings — aligning virtual and real sound sources is not necessary. Hence, we see registration as only one of the ways by which virtual content can be related to the real environment and require ‘a relationship’ rather than registration.

Opposed to common trends, we do not consider interaction between a user and the added content decisive for AR. Instead, we emphasize the importance of interaction between the virtual and that what it augments. However, artworks like David Rokebys *Very Nervous System* [13] illustrate that these different types of interaction are not necessarily in conflict: interaction between an audience and virtual content can act as the relationship between the virtual and that what it augments.

Considering the identified relationships between the virtual and the real, we do not claim that we have presented an exhaustive list. Often several relationships are present in the same AR scenario. Therefore the identified relationships should not be understood as mutually exclusive categories.

Concluding our discussion, we want to return to the example of the radio. While we have argued that the sounds of a radio do usually not augment the environment, we can now envision scenarios where this is the case. Simply singing or dancing along with the radio, the virtual and real are combined and related. This reminds us, that the virtual does not always have to be added to the real: the other way around is also possible.

## 5 Conclusion and Future Directions

Starting out from common understandings of AR, we have developed an encompassing, technology-independent, sense-independent and conceptual view of augmentation. We have pointed out that it does not suffice to combine the virtual and real in order to create AR and have argued that a relationship between the virtual and the real is required. Compared to common definitions, our conception of AR is much broader. Therefore, it suggests many possible forms of AR that have received little attention in AR research and in practice so far.

Possible future directions include the exploration and design of novel relationships between the virtual and the real, e.g., in the form of interaction between both. With respect to this, we think of art and AR as two disciplines that can contribute to and inform each other. The presented overview of existing and possible future relationships can serve as a basis for designing future AR works as well as contribute to future classifications and characterizations of AR.

Interesting fields for future research and practice are furthermore *non-visual*, *cross-modal* and *multi-modal* AR. Up to now the most common form of AR is based on virtual visual content that primarily relates to what we see. Similarly, we have shown that sound can augment the sonic environment. What about alternative possible combinations of modalities? How could visual content augment what we hear, sound augment what we smell, or touch relate to what we hear? We expect that this sparsely explored field offers various possibilities to combine and relate the virtual and the real in novel ways.

We have argued that AR can not only augment the environment. We wonder whether it is also possible to augment moods or feelings. And what about augmented thoughts? Considering this suggests the more general question of whether AR is bound to real space. These considerations pose interesting issues for future investigations into the meaning, impact and possibilities of AR.

Regarding the continuation of this work, we plan on developing a framework that allows us to classify AR scenarios by specifying the virtual, the real and their relationship. Furthermore, we want to address topics that have only been touched upon briefly, such as possible interactions between the virtual and the real that are impossible to realize between real objects.

We hope this research will foster AR works in which the virtual and real no longer merely ‘appear to coexist in the same space’ (cf. [1,2,6]) but enter an active dialog.

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