From Coexistence to Interaction: Influences Between the Virtual and the Real in Augmented Reality

Hanna Schraffenberger, LIACS, Media Technology Research Group, Leiden University, 2333 CA Leiden, The Netherlands & AR Lab, Royal Academy of Art, The Hague, The Netherlands. E-mail: hkschraf@liacs.nl

Edwin van der Heide, LIACS, Media Technology Research Group, Leiden University, 2333 CA Leiden, The Netherlands. E-mail: evdheide@liacs.nl

Abstract

This paper examines the interaction and influences between the virtual and the real in Augmented Reality (AR). We explore how real objects can affect virtual objects and vice versa. Our work is based on theoretical considerations, a review of existing research and artworks as well as our own initial series of experiments. We argue that virtual and real objects can not only simulate influences that exist between real entities, but also influence each other in new and imaginary ways that have no equivalent in the physical world.

Keywords: Augmented Reality, Interaction, Interactive Art, Electronic Art, Mixed Reality, Virtual Reality, Virtual, Real, Interaction Models

In Augmented Reality (AR), virtual content is added to our real environment. This enables new and unique relationships between the two. So far, much work in the field has focused on scenarios where virtual and real objects appear to coexist in the same physical space. By contrast, our research is concerned with AR (art)works in which the virtual and the real not only coexist but also influence and interact with each other. We envision scenarios where real wind moves virtual leaves, where real doors open for virtual objects (see Fig. 1), where virtual singers shatter real glass and where virtual objects get wet when it rains. Moreover, we hope for the creation of works in which virtual and real objects interact in novel ways and where AR allows us to experience influences between objects that cannot exist in a purely physical world.

Our research is inspired by two simple theoretical considerations. First, that the virtual is free from physical laws. Hence new forms of interaction could be possible. Second, that the virtual cannot directly apply forces to real objects. As a consequence, interactions that we know from the physical world might not be possible. This inspires us to ask the following questions:

- What types of interaction between the virtual and the real are possible?
- When/how can the real affect the virtual?
- When/how can the virtual affect the real?
- What makes the interaction believable?
- Which problems do arise?
- Which possibilities do emerge?

In order to explore the possible interactions and influences between the virtual and the real in AR, we have reviewed existing AR (art)works and literature and have also conducted an initial series of experiments. Our research is motivated by our own fascination with the topic and is intended to foster experiments, artworks, exchange, and discussions among scientific, augmented reality, and electronic arts communities. Furthermore, we intend to learn more about the fundamental characteristics of AR and its possibilities for electronic art.

Research Context

We are interested in AR scenarios in which the real affects the behavior of the virtual and/or the virtual affects the behavior of the real.

An interactive installation in which the real environment affects the behavior of virtual objects is the car racing game *Room Racers* [1] by Lieven van Velthoven. Unlike traditional computer games, which are displayed on a screen, this game takes place in real space. Virtual cars are projected onto the player's floor. Real objects, such as shoes, keys and toys are placed on the ground and define the racing course. During the game, players can steer the cars around the track with traditional game consoles. The physical objects act as obstacles that cannot be crossed by the virtual cars. In our work, we are interested in taking influences between the virtual and real one step further. We consider cases in which the virtual is not only affected by something real but also influences the real in return. We call such bi-directional influences interaction.

The idea of interactions between the virtual and the real is also present in AR research. Several studies have introduced physics simulation in AR and with it interaction between virtual and real objects (see, for example, [2,3,4]). What sets our work apart from many existing studies is our interest in novel forms of interaction. We are not only concerned

Fig. 1. Real doors open for virtual objects. (© Hanna Schraffenberger and Edwin van der Heide.)

with realistically simulating interactions that we know from the physical world but wonder: Does AR allow us to realize imaginary influences that could not exist in a purely physical form?

Our work can be regarded as a response to the research undertaken by Kim, Kim and Lee [5]. The authors demonstrate that problems can arise when real and virtual objects collide because virtual objects cannot apply forces to real ones. We have observed the same phenomenon and explicitly explore ways in which the virtual can (appear to) affect the real.

We focus on interaction between virtual and real *objects*. The interaction between *users* and virtual content falls out of the scope of this paper.

This research builds upon our preceding work regarding the believability of the behavior of interactive artworks [6] and our studies on the relationships between the virtual and the real [7]. In the latter, we have argued that these relationships are a defining aspect of AR and we have identified interaction between the virtual and the real as a promising area for future research.

Exploration

In order to explore if and how the virtual and real can interact, we conducted an initial series of experiments that test our theories and serve as illustrative examples.

Realism

The first experiments explore to what degree virtual and real objects can (appear to) physically interact like real objects.

Example 1: Bouncing Ball

Our first simulation recreates (what we consider) a simple real-world interaction: a ball that bounces on a surface (similar experiments have been conducted by Valentini and Pezzuti [8], Kim et al. [9] and Chae and Ko [10].) Our setup consists of a laptop that runs self-written

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Page numbering begins at 1 at the start of the paper.

Fig. 2. A virtual ball is bouncing on a real table. Four snapshots from the live-view. (© Hanna Schraffenberger and Edwin van der Heide.)

Max/MSP/Jitter software and a webcam that provides a live-view of the environment. The software integrates the virtual ball in the view of the environment. In order for the ball to react to its real surroundings, we have created a virtual 3D reconstruction of the environment and aligned it with the real scenery. Furthermore, we have assigned virtual physical properties such as mass and restitution to the virtual elements and applied gravitational forces (using the Max/MSP/Jitter physics engine). The experiment is a success: When we start the simulation and view the environment through the screen, a virtual ball appears to bounce on the desk in front of us (see Fig. 2).

The outcome shows that it is possible to simulate certain existing real-world interactions in AR. However, on second thoughts, it becomes clear that the virtual ball does not have any effect upon the real table. In fact, the example only shows that the real can influence the virtual.

Example 2: Dominoes

As a next step, we deliberately chose a scenario that seemed bound to fail. In this experiment, a virtual ball collides with a row of real dominoes (see Fig. 3). Initially the screen shows the virtual ball heading towards the real dominoes. Just like in the previous example, the virtual ball reacts to the real: the moment it hits the first stone, the ball changes its direction and turns back. However, unlike in the real world, the stones do not fall.

This behavior contradicts our expectations and is not believable. We seem to expect a realistic response and want to see the stones falling. Clearly, problems can arise due to the fact that the virtual cannot directly affect the real. This problem has been noted earlier by Kim et. al [11] who call this the 'physical artifact'. Intrigued by the problem, we ask: What possibilities are there for the virtual to influence the real? What forms of interactions are believable nevertheless?

The Virtual Affects the Real

There are several possible ways in which the virtual can affect the real. One possibility is to work with *hybrid objects* that have both a virtual and a physical presence. We have explored these options by extending the previous examples.

Example 3: Falling Stones

In this example, again, a virtual ball is heading towards a row of dominoes. However, this time, when the ball hits the first domino stone, the stones start falling. This happens because we have extended the virtual sphere with a physical body — a real ball acts as the physical counterpart for the virtual ball. While looking at the scenery directly, one sees a physical ball. The screen, however, shows a virtual ball instead. We realized this by analyzing the camera-image and replacing the real ball with a virtual one. What makes this interesting is that we can also replace the real ball with any other virtual object and thereby give it qualities that the real object does not have. This approach is found in the commercial product *Sphero*, a robot ball that – when viewed with the corresponding smartphone app – is turned into a virtual beaver [12].

Example 4: Resonating Desk

Physical interaction cannot only be observed visually. If we compare our bouncing-ball example with the bouncing of a real ball, we notice that something is missing in our simulation. When the real ball hits the table, the collision produces a distinct sound – the table resonates. Also in the simulation, the real should react to the impact of the virtual. In order to achieve this, we have extended the experiment and trigger matching sound samples when the virtual ball and the virtual representation of the table collide (we use the magnitude of the collision to calculate the volume and randomly choose one of several impact-sounds each time). This example shows that sometimes we need to extend real objects (– the table –) by means of the virtual (– the sound samples –) in order to simulate a realistic response.

Actuators

A yet different approach is to extend the real with electronics such as actuators [13]. The virtual can then move or transform the real by controlling these actuators. Kang and Woo [14] have implemented this concept. In their research, they extend a physical toy cart with electronics so that a virtual character can push and pull the cart. Likewise, one can modify those real objects that already are equipped with electronics that react to the environment. For example, automatic doors that open when someone enters the space in front of them can be modified to also open when something virtual moves in front of them.

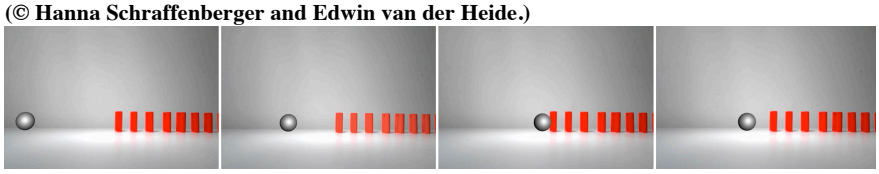
Analogue Interaction

The interactions discussed so far rely on computer-simulation. An artwork that demonstrates that real objects can interact with virtual content without the use of simulation-techniques is *Radioscape* by Edwin van der Heide [15,16]. The installation consists of several radio transmitters that are distributed over a part of a city. Each transmitter broadcasts one layer of a meta-composition. Listeners can pick up several signals at a time with a custom developed receiver. The volume of the single layers depends on the listener's distance from 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 affecting the virtual content and influencing what one hears. Although this interaction happens in the physical domain, we can argue that the virtual content interacts with the physical landscape. Another example of interaction that occurs solely in the physical domain is a virtual opera singer who, when their voice hits the right pitch and is played back at the right volume, shatters a real glass.

Imagination

The preceding exploration has shown that the virtual and the real can influence each other and that real-world interactions can be simulated in AR. In the following, we propose that, besides simulating reality, there is another way

Fig. 3. A virtual ball approaches a row of dominoes (frame 1 and 2), hits the first stone (frame 3) and rolls back (frame 4). Unlike in the real world, the stones do not fall. (© Hanna Schraffenberger and Edwin van der Heide.)



of creating believable influences between the virtual and the real: imagination.

The virtual does not have to obey physical laws. Hence, it can behave in novel and unrealistic but – according to our hypothesis – nevertheless believable ways. We do not think that virtual objects have to move like real objects in order to appear believable. More fundamentally, virtual objects do not have to represent real objects. For example, we can easily imagine a virtual ghost that floats through real walls. Just as we accept imaginary objects with their own behaviors in books, computer games and in cinema, we can accept different sorts of objects and different forms of behavior in AR. Presumably, if the virtual represents a real object and behaves like a real object, we expect it to affect the real environment just like a real object. However, we assume that if the virtual does not appear and behave like a real world object, we do not have such expectations. Are these assumptions true? What makes a certain behavior believable? What influences can we imagine?

Example 5: Attractive Colors

We have explored a first scenario in which virtual objects react to the real environment in an imaginative way. In this experiment, virtual objects are attracted by real objects of like colors. The setup includes a cloud of small virtual spheres – half of them with bluish colors and the other half with yellowish colors and one blue and one yellow rubber ball. As soon as the rubber balls enter the scene, they attract spheres of like colors (see Fig. 4). Although the virtual spheres do not imitate the behavior of real objects and do not obey the same physical laws as real objects, the relationship between the virtual and the real is easily understood, intuitive and believable. The fact that the virtual has no influence on the real is not a problem.

Even though the example is based on physical forces (attraction), it leaves behind the realm of realistic physical interaction as we know it. It becomes clear that the virtual does not have to behave like a real object in order to be believable. Furthermore, the example shows that influences between the virtual and the real bring great possibilities for interaction between an audience/user and the augmented environment: If physical objects influence virtual ones, the audience can interact with the augmented environment simply by interacting with physical objects [17].

Conclusions & Future Directions

Our exploration has shown that influences between the virtual and the real can take different forms. Firstly, they can simulate influences that exist between real entities. In addition to this, they can also take on new and imaginary forms that have no equivalent in the physical world. In line with this, there are two approaches to creating believable influences and interactions: the imitation of reality and the creation of imaginary realities. Kim et al. have claimed that in order for virtual objects to move as if they coexisted with real ones, they should obey the same physical laws as the real objects [18]. Judging from our current exploration, this is not necessary. Future work (both research and artworks) can explore the ways in which the virtual and real can interact in AR in novel ways.

In the course of this exploration, we have focused on visual AR. In the future, it would be especially interesting to explore the possibilities of non-visual, multimodal and crossmodal interactions and to include other physical properties of the environment. For example, real wind might move virtual leaves and the temperature of the environment might affect the behavior of virtual creatures.

We have noticed that influences between virtual and real objects support interaction between users/audiences and the virtual content. We would like to explore this interaction in the future. We hope this research will inspire both researchers and artists to explore the topic further. We believe that relating the virtual and the real by means of interaction can result in exciting artworks as well as novel manifestations of AR. We hope that our research serves as a first step towards works in which the virtual and the real not only coexist but also interact.

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References and Notes

1. Lieven van Velthoven, Room Racers (2011), interactive installation, <www.lievenvv.com/Projects/RoomRacers.htm>, accessed 6 July 2013.

2. Changhun Chae and Kwanghee Ko, "Introduction of physics simulation in augmented reality," *ISUVR 2008*, pp. 37-40. (IEEE, 2008).

3. Sinyoung Kim, Yeonjoon Kim and Sung-Hee Lee, "On Visual Artifacts of Physics Simulation in Augmented Reality Environment," *ISUVR 2011*, pp. 25-28. (IEEE, 2011).

4. Pier Paolo Valentini and Eugenio Pezzuti, "Interactive multibody simulation in augmented reality," *Journal of Theoretical and Applied Mechanics* **48**, No. 3 (2010) pp. 733-750.

5. Kim et al. [3]

6. Edwin van der Heide, "Believablity," *AR[t] magazine* **3** (May 2013), <http://www.arlab.nl/tags/art-magazine>.

7. Hanna Schraffenberger and Edwin van der Heide, "Towards Novel Relationships between the Virtual and the Real in Augmented Reality," *Arts and Technology*, pp. 73-80 (Springer Berlin Heidelberg, 2013).

8. Valentini and Pezzuti [4]

9. Kim et al. [3]

10. Chae and Ko [2]

11. Kim et al. [3]

12. Sphero, <http://www.gosphero.com/sphero-debuts-groundbreaking-augmented-reality-app/>, accessed 6 July 2013.

13. Kim et al. [3]

14. Changgu Kang and Woontack Woo, "ARMate: an interactive AR character responding to real objects," *Edutainment Technologies. Educational Games and Virtual Reality/Augmented Reality Applications*, pp. 12-19 (Springer Berlin Heidelberg, 2011).

15. Edwin van der Heide, "Radioscape in the context of Augmented Reality," *AR[t] magazine* **2** (November 2012), < http://www.arlab.nl/tags/art-magazine>, see also: <http://www.evdh.net/radioscape/>, accessed 6 July 2013.

16. Schraffenberger and van der Heide [7]

17. Ibid.

18. Kim et al. [3]

Fig. 4. The colored rubber balls attract virtual spheres of similar colors. (© Hanna Schraffenberger and Edwin van der Heide.)