# HoloR – A Spatial AR prototyping environment for wide FOV AR applications

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**Abstract**

Current augmented reality (AR) glasses suffer from low field-of-view (FOV). AR content is usually created with this limitation in mind and thus provides primarily small volume experiences. This paper discusses a selection of AR interactions in the context of everyday life that would benefit immensely from an increased FOV. For each proposed experience, we present and discuss a working proof-of-concept implementation that has been created using our spatial AR system to provide the necessary FOV. We provide a video showing the proof-of-concept applications as supplementary material[1].

## 1 Introduction

Augmented Reality (AR) will change how we interact with our physical and digital environments, allowing to blend context and data into our real-world experience, ultimately creating the illusion of presence and persistence of virtual objects. The limited FOV of current AR systems force developers to design for *focused interaction*, where augmentations are confined to small areas around the optical axis and disappear when looking somewhere else. The importance of FOV has been investigated primarily in the following domains: A wider FOV is linked to an increase of self-reported presence in VR settings (Cummings and Bailenson, 2016). We assume that a similar link applies to the concept of object permanence in AR settings. Object permanence describes the

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understanding that an object exists independently of our ability to perceive it (Piaget, 1970). Since virtual objects tend to disappear at the display boundaries more often for devices with lower FOV, we assume that the impression of a virtual AR object as ”present” at a certain location will increase for higher FOV. Assuming that the disappearance of an otherwise persistent object qualifies as an ”impossible event” that causes stimulation and inhibits habituation (Baillargeon et al., 1985), we expect an increase in object permanence to correlate with less cognitive load and a calmer co-presence in AR settings.

Ambient displays often augment household objects for the same reasons. The ability to create persistent virtual objects in AR settings could extend ambient intelligence to the virtual realm. A wider FOV appears to also enhance the performance of certain search tasks in the spatial domain (Kishishita et al., 2014; Ren et al., 2016). Locating objects is a common task in everyday life. A wider FOV could be utilized to provide attention guiding in the far peripheral field and show relationships between distributed objects.

In summary, we consider a very large (>150°) FOV to be especially useful in AR settings, where

- the impression of AR objects' permanence is important,
- the peripheral view contains relevant information,
- AR objects or their relationships cover a larger volume.

## 2 Simulation of wide FOV using spatial AR

AR can be experienced using (i) hand-held devices, (ii) see-through HMDs or (iii) via AR simulation in VR. Let's discuss these according to their FOV. Hand-held devices such as smartphones and tablets offer only a very limited FOV and limit finger-/hand interactions as an input modality. See-through HMDs such as Microsoft HoloLens offer detection of hand and finger gestures but are still quite limited in their FOV (≈30°). Simulating AR within VR utilizes the comparably large FOV of current VR systems (≈100°) and is promising especially when evaluating new AR interface patterns (Ren et al., 2016; Renner and Pfeiffer, 2017). However, it is difficult to replicate everyday situations and ambient settings in VR due to potential misalignment of virtual world and real-world, incomplete or inaccurate representation of one's own body as well as VR sickness and presence issues.

While upcoming devices and prototypes such as “Magic Leap” or “Project North Star” are promising, they are currently not available for a broader audience. In order to investigate the potential of AR in ambient settings, we developed the HoloR (Holographic Room) system, a spatial projection AR system installed in the Ambient Intelligence Laboratory at CITEC, Bielefeld (Schwede and Hermann, 2015).

A total of 5 projectors render a 9600 ×1080 pixel canvas in SBS stereo at 60 fps using 120 Hz shutter glasses. The room has a floor size of approximately 60 $m^2$ and the area (walls and furniture) being projected on is roughly 80 $m^2$. The system supports spatial audio either via headphones and HRTF or VBAP across 30 loudspeakers distributed across the room. Eye positions are estimated using either a calibrated set of 4 Kinects or a low-weight (80 g) wearable Vive Tracker.

Average motion-to-photon latency[2] is between 50 ms (Vive Tracking) and 125 ms (Kinect). Integrated interaction and inputs methods are gaze direction, speech recognition and finger tracking using Leap Motion and OpenPose (Simon et al., 2017). In order to allow rapid prototyping of ambient AR applications during short term student projects and workshops, content can be created either via JavaScript/WebGL or higher-level engines such as Unity or Unreal Engine (see forest scene in Fig. 1).

*Figure 1: Virtual Home Decorations: Different wallpapers and forest landscapes*

# 3 Applications

We present a selection of use cases and discuss a corresponding proof-of-concept implementation using our HoloR system described above.

[2]time between physical motion and the corresponding effect on the pixel in the **center** of the display

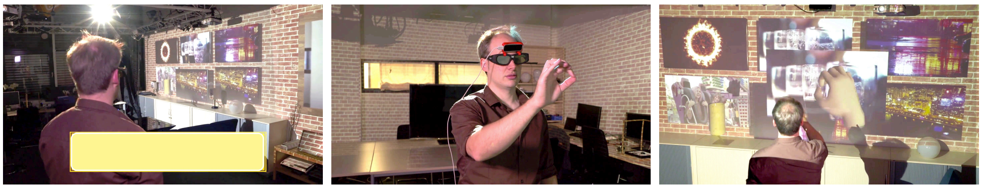

*Figure 2: Virtual TV and media selection using Leap Motion*

## 3.1 Ambient Intelligence

Calm computing involves novel user interfaces that respond to the current user's context and can blend into the environment (Weiser and Brown, 1996). Ideally they should be easy to ignore when not in use. This has been traditionally solved in Ambient Intelligence by using physical, common household objects, such as lamps (Shen, 2009), art (Skog et al., 1999), pillows (Nack et al., 2007), shower curtains (Funk et al., 2015) or even living plants (Hammerschmidt et al., 2015).

Since they serve a regular purpose in day-to-day activities even while not being active it is assumed that their consistent presence will provide a calmer[3] experience even when enabled. This process of turning everyday objects into ambient displays can be understood as a form of AR, since the purpose of the object itself is usually not changed but extended (or augmented) by providing additional information in the corresponding context.

For these scenarios, AR could be used to render objects that appear non-salient and unobtrusive in the context of daily experiences. Being virtual they are not bound to physical constraints and as such could change dynamically based on the information to be conveyed.

As of yet it is unclear how virtual ambient displays perform in comparison to their physical counterparts. Has a large FOV a similar effect on object-permanence in AR as on self-presence in VR? How does the ability to dynamically change appearances in an AR setting interfere with the mantra of calm computing that (simplified) "the less change the better"?

## 3.2 Home Decoration and Media Access

Currently there are only a few options to dynamically change the appearance of home environments. Light systems such as Philips Hue allow to change ambient light conditions but are limited in their effects and bound to physical installation constraints. Flat TV screens have been suggested as virtual windows or fireplaces (IJsselsteijn et al., 2008).

[3] in the sense of calm technology, Weiser and J.S. Brown

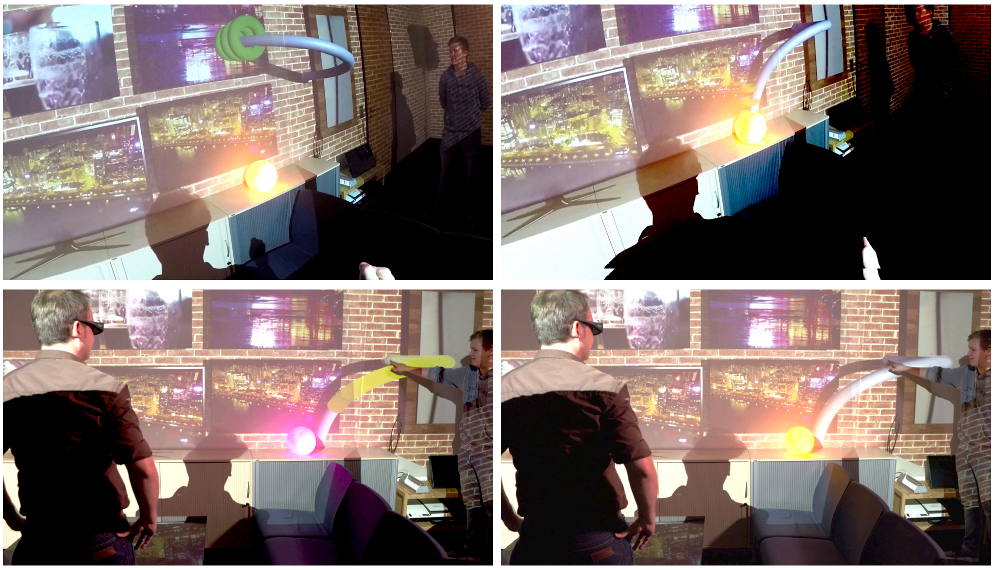

*Figure 3: Virtual Wire: a wire is attached to a physical switch first, then to a physical lamp, the press of a button creates an event that flows through the wire, the lamp switches color upon receiving the event*

A wide-FOV AR system allows to significantly alter the room's appearance. We implemented a number of 'room appearance alterations' using the HoloR system so that we can experience these augmentations before unobtrusive wide-FOV-AR-gears become available. This includes changing colors, wallpaper textures and virtual landscapes (see Fig. 1).

Objects with a primarily decorative purpose could be replaced entirely with dynamic virtual objects rendered in AR. Virtual TVs can show content with dynamic size and placement (see Fig. 2). Social media content can be rendered to appear like physical picture canvases.

## 3.3 Home Control

An increasing amount of household devices can be accessed and controlled via the Internet. The increase in potential complexity to interconnect these is reflected in an increasing effort to standardize interfaces across IoT devices and to simplify UI. The general process of connecting "smart" household devices usually comprises a mode of wireless discovery and pairing in a menu- and hierarchy-based smart-phone application. In order to distinguish similar components in the same household, their spatial relation or context is often encoded explicitly within their labels or hierarchy (e.g., "Upper Switch Kitchen Door" or "Lamps Dining Room").

AR allows to access and connect these components in their spatial context. In our proof-of-concept implementation **"Virtual Wire"**, we can connect virtual and physical devices using the metaphor of *virtual wires*. In order to have a certain light turn on once a certain switch is pressed, the user can lay a cable (floating in 3D-space) connecting the two as shown in Fig. 3). Whenever a configuration needs to be changed, activating the AR mode temporarily gives an immediate overview of all configured component bindings. A shared AR view could further allow visitors and guests to quickly learn how to operate the appliances without requiring explicit instructions from the house-owner.

We assume that this will reduce the mental effort to create and understand the configuration of smart household appliances and that the system will be especially helpful in debugging control issues by visualizing the spatial event flow. For future work we consider the integration of a visual programming languages to allow more advanced rules and a comparative UX study highlighting differences to traditional approaches.

## 3.4 Virtually transparent objects and portals

The advent of neural networks in computer vision has improved detection rate for physical objects in sight of any camera considerably during the last decade. This allows machines now to aid in identifying and locating objects, as for instance to guide users to where they left their keychain or mobile phone.

In the case of retrieving missing objects, an effective method is needed that provides quick and effortless guidance for retrieval.

We developed two proof-of-concepts showing the idea of dynamically turning opaque containers or walls transparent using our HoloR system (see Fig. 4). **"Virtual Cupboard"** is a cupboard equipped with a webcam recognizing objects using a CNN that was trained on the ImageNet database (Deng et al., 2009). Once a known object is placed within the cupboard, a corresponding 3D model is being augmented as 'in the cupboard', i.e. users see it consistently as located in the cupboard whose opaque elements are rendered as "virtually transparent". This type of solution is not constrained

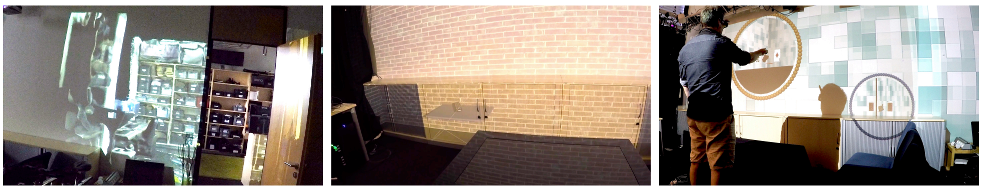

*Figure 4: Virtual transparency: Virtual ARLab, Virtual cupboard, Virtual Portals*

to objects present within the same room. In HoloR, we can render a wall transparent by showing a 3D model of the world behind it, e.g. to show visitors outside the main door. **"Virtual ARLab"** shows a static 3D mesh of the lab next door that is overlayed with a live Kinect 3D view. (see figure 4). We envision this mode of selective transparency to be useful for the 'leaving your house' scenario: users could quickly "scan" all rooms for e.g. windows left-open, which could in turn be closed simply by operating a virtual window handle with a hand gesture that reaches through the transparent wall. A related concept of remote interaction was inspired by the game "Portal". **"Virtual Portal"** can thus provide an interaction "warphole" between distant locations, within the own home, or even to connected rooms.

A proof-of-concept implementation is depicted Fig. 4, (right panel): Three backward-facing playing cards are placed above a sideboard. The user can place one distant portal immediately behind the cards (blue portal on the right) and create a new one in a more comfortably reachable distance (yellow portal on the left). Light and objects that enter one portal will 'travel through the wormhole' and exit on the other one. This way, the user is able to see the back of the cards through the yellow portal (i.e. the transfer of light is simulated by rendering a corresponding viewpoint behind the other portal) and also to manipulate them directly, in our case using a Leap Motion to create a virtual hand which exits the blue portal if put through the yellow portal).

# 4 Conclusion

This paper presented a selection of use cases that would benefit in particular from wearable wide FOV AR glasses. Since these displays are not yet available, we used HoloR, our spatial AR system to prototype, implement, experience and thus explore corresponding use cases in proof-of-concept applications. The swift realization enabled us to better understand and highlight the potential of those use cases to enhance activities in day-to-day life and to identify relevant research questions, as listed in the sections above. We are currently on the brink of AR not only replacing the smartphone as the default information medium but enabling new types of interactions in settings that were neglected in HCI contexts. We hope that this paper will encourage AR content creators and researchers to also widen their FOV and explore these expanded AR interaction spaces.

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