Virtual Reality, Augmented Reality, Mixed Reality, Holograms and Holodecks

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ABSTRACT

This paper provides a preliminary overview of different forms of reality, comparing and contrasting them with one another. It argues the definition of the term "reality" is ambiguous. This motivates an internalization of elements from a technology standpoint, e.g., biological, 3D printed, Flying Light Speck illuminations, etc.

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1 INTRODUCTION

There is a lot of excitement about Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), holograms, and holodecks. This excitement is further fueled by forward looking press/video–releases by gaming, social networking, and technology companies. This short article presents a high-level overview of these technologies using examples, highlighting their synergy that demonstrates reality is ambiguous and subjective. We provide references for the reader to follow the different technologies in greater detail and to better understand the subjective nature of reality that impacts the provided definitions.

Virtual Reality (VR) glasses and head mounted displays (HMDs) immerse a user in a virtual world of images and sounds, isolating the user from the physical world. The user may navigate this virtual world and manipulate its objects using haptic gloves and joysticks. Examples include flight simulators that may seat a user in a fake cockpit and VR games for HMD offerings by vendors such as Oculus Quest 2, PlayStation VR, HTC Vive among others.

Several studies evaluated the feasibility of haptic feedback in a VR environment. For example, TactileDrones emulate a bug bite in a virtual environment using quadcopters with sharp end-effectors that poke users [15]. This is a form of an active haptic device using quadrotors [1, 25]. Active haptics include wearables that range from gloves with vibrotactile actuation [6] to haptic shoes [8] and full body suits [17], handheld devices [16], and robots [19] that include ground simulators [18]. With tactile feedback, ultrasonic transducers have been used to generate air pressure that stimulates the user's skin [22–24].

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Augmented Reality (AR) overlays virtual objects on top of the physical world. A user sees these objects using glasses, see-through HMDs, or screens at their physical location. Pokemon Go is an example using mobile screens. In addition to visual elements, AR may include acoustic and haptic elements [14].

Mixed reality (MR) merges real-worlds and computer-generated ones and allows physical and virtual objects to co-exist and interact. It gathers information about a user's surroundings and interactions, facilitating seamless transitions from the physical world to the digital world. For example, a user wearing a MR visor may write a post-it note in the virtual world and stick it on a real world refrigerator. This note may be visible only when the user wears the MR visor and looks at the refrigerator. Retail MR examples include trying out clothes before purchasing them and walking through the aisles of a store interacting with the products to make informed purchases without human assistance.

Augmented Virtuality (AV) is the reverse of AR and MR. It is a virtual environment extended with physical reality. A simple example is to enable a user to make a video conference call from a virtual environment. Another example is a device that enables a user to blow on its microphone to generate bubbles in a virtual world or place the face of a real person on a virtual character.

The current literature uses AR and MR interchangeably. An early taxonomy defines MR to encompass both AR and AV [20].

A hologram illuminates a virtual object in the physical world. There exist holographic near-eye displays used in VR/AR/MR glasses, goggles, visors, and HMDs. See [4] for an overview. There are also direct displays that free a user from glasses to see the object with the naked eye, enabling multiple users in the same physical space to see the hologram. Direct displays complement AR and MR. A user may wear their AR glasses to observe a virtual object associated with a hologram. Or, use their MR glasses to interact with the hologram. For example, each piece of a game of Chess may be a hologram on a physical wooden board. Wearing MR glasses, a user may observe and move a holographic Chess piece on the board.

The example use of AR glasses with a hologram demonstrates reality is ambiguous. If a hologram is a virtual object, say a Pokemon, what reality has been augmented by AR? Pokemon does not exist in reality. Its hologram is an illumination that does not occupy the physical world. At the same time, augmented reality is associating other virtual objects with a Pokemon, a virtual object. One way to resolve this dilemma is to define virtual "object as one which appears transparent, that is, which does not occlude other objects located behind it" [21]. While this definition addresses the ambiguity in this specific scenario, we see it fail in the context of a holodeck as described below.

A holodeck is a chamber or facility in which a user can experience a holographic or computer-simulated physical environment. A holodeck enables a user to see virtual objects without glasses and to interact with them without wearing gloves. It will occupy a physical volume such as a table top cuboid or sphere, a telephone boot, a room, a concert hall, or a stadium. It may use holograms, 2D screens, fast 3D printing, and miniature drones with Red/Green/Blue (RGB) lights that fly as swarms to illuminate a virtual object [9]. (The drones are termed Flying Light Specks, FLSs [10, 11]). With 3D printing and FLSs, a holodeck will materialize a representation of virtual objects in the physical world, enabling one or more users to interact with (e.g., touch) them in the physical world.

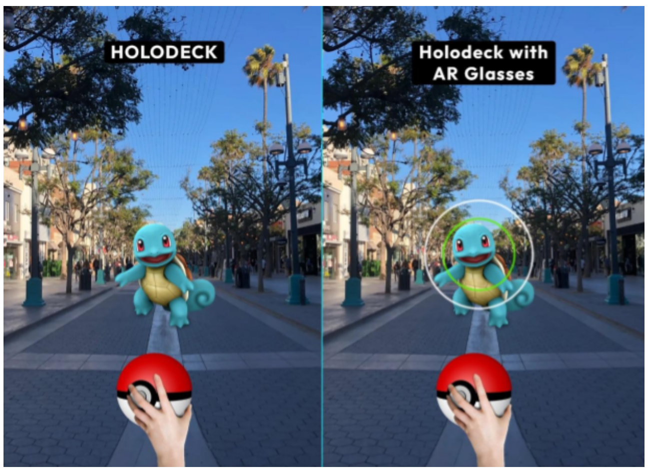

Figure 1: Left: A user's view of a Pokemon illuminated in a Holodeck with the user holding a Poke Ball to throw. Notice the target on the Pokemon is missing. Right: The user may wear their AR glasses in a Holodeck to see the target on the Pokemon when throwing the Poke Ball.

Similar to the hologram discussions, a user may wear their AR and MR glasses to interact with holodeck renderings seamlessly, see Figure 1. When compared with MR, a holodeck will introduce a new capability. A user may move virtual objects from MR (and potentially AR) into a holodeck for interactions without glasses and gloves. Today's 3D printers perform this task to a certain degree. They materialize the blueprint of a car from the virtual world of a computer into a physical car.

Earth with all its positioning satellites may serve as a holodeck. For example, FLSs may assemble into a Pokemon at a street corner that is visible to all players and non-players. All will see the Pokemon balls thrown by different players and the ball that catches the Pokemon. (A ball is also illuminated using a swarm of FLSs.) To prevent human injury and damage to physical property, an FLS swarm may disperse once perturbed by an external force that exceeds a pre-specified threshold. This threshold may be set such that a person may touch the Pokemon. However, once the force exerted by the touch exceeds the threshold then the FLSs that are rendering the Pokemon disintegrate.

FLS illuminations and 3D printed artifacts blur the boundary between real and virtual. Is the street corner Pokemon illumination real or virtual? One way to make the distinction is to define virtual objects as models or simulations while real objects are sampled and synthesized by some device [21]. The obvious counter-argument is that an FLS illumination (or a 3D printed artifact) may be sampled and synthesized by some device. These debates may be moot if we stop distinguishing between real and virtual in a few years from now, internalizing elements from a technology standpoint, e.g., biological, FLS illumination, wooden, 3D printed, organic, hologram, etc.

2 CONCLUSIONS

VR, AR, MR, and holograms are not new. Despite their recent commercial use, MR dates back to the 1990s, VR and AR technology trace back to the 1960s, and holography to the 1940s. Elements of a holodeck exist in the form of drone light shows (dating back to 2012) and 3D printers (1970s with US patent US3596285A).

A key difference between a holodeck and the other alternatives is that objects are materialized. A user may see them without wearing glasses or head-mounted displays and to touch them without wearing gloves or bodysuits. Example systems include fast 3D printing [7], Claytronics as physical artifacts using programmable matter consisting of catoms [12], Roboxels as cellular robots that dynamically configure themselves into the desired shape and size [19], BitDrones [13] and GridDrones [3] as interactive nano-drones, and Flying Light Specks (FLSs) as miniature drones with RGB light sources that fly as swarms to illuminate a virtual object [2, 5, 9–11].

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