Maintaining and Enhancing Human-Surrogate Presence in Augmented Reality

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Abstract

We present some background and ideas related to a human's sense of presence with a human surrogate (a stand-in for a human) in an augmented reality (AR) setting. In particular we examine several factors related to human surrogates that are common to robotics, virtual reality, and augmented reality; and some challenges that are unique to AR. We then discuss the roles of surrogate characteristics and behaviors in maintaining and perhaps enhancing a sense of presence with a surrogate. We conclude by sharing some ideas for intentionally employing particular surrogate characteristics/behaviors that could simultaneously address the AR-specific challenges while maintaining and perhaps even enhancing the sense of co-presence/social presence with human surrogates in AR.

Keywords: Human surrogates, avatar, virtual human, presence, augmented reality, social interactions, context-aware.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, Augmented, and Virtual Realities; J.4 [Computer Applications]: Social and Behavioral Sciences—Psychology

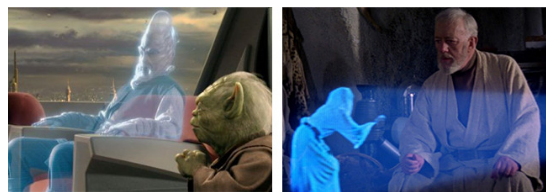
1 Introduction

Technology-based human surrogates (e.g., virtual humans or humanoid robots) have been growing in popularity due to their current and potential usefulness in our lives. These days, human surrogates are used in many tasks where real humans are not ideal (or possible), or where the use of human surrogates is otherwise beneficial. In robotics for example, (humanoid) robots are replacing real humans in manufacturing environments, and exploring/navigating robots play important roles in some scenarios such as tasks related to space research [22]. Virtual humans have been also very actively used in various fields, for instance in military simulations, healthcare training, and education [9, 30]. Although there have been many applications using human surrogates, many cases are still limited to constrained scenarios or environments, such as in laboratory environments. However, thanks to the continued improvements in technology, e.g., augmented reality (AR) or wearable computing, we continue to see an increase in the potential use of human surrogates in our ordinary everyday lives, for example as conversational partners or personal companions.

Here we consider three different types of human surrogates: robotic humans (RHs), virtual reality humans (VHs), and augmented reality humans (AHs). For example, RHs in the form of humanoid robots have appeared in films such as "Sonny" in "I, Robot" or "Andrew" in "Bicentennial Man." These RHs have a physical body and can physically interact with real humans and their environments (Figure 1a). VHs are computer-generated animated graphics that we can see via display devices (e.g., TV screen, HMD, or projection), such as video game characters in a virtual space (Figure 1b). Because of the completely separate nature of the

(a) Robotic human examples: "Sonny" in "I, Robot" (left) and "Andrew" in "Bicentennial Man" (right).

(b) Virtual human examples: Uncharted (left) and Halo (right).



(c) Augmented human examples: Holograms in "Star Wars".

Figure 1: Different types of human surrogates.

physical real space and the virtual space there is an effective barrier between real humans and VHs. Like VHs, AHs are also computer-generated graphics, but the AR technology involved in the rendering and display of the virtual characters makes AHs different from VHs. Unlike VHs, because AHs are rendered in a real space, human users might perceive the AHs as sharing the real space. Holograms in the film "Star Wars" offer examples of AHs (Figure 1c).

Apart from the technical perspectives, researchers in social/cognitive science or psychology have been interested in real human *perceptions* of human surrogates, and the associated *social influence*. In this context, human perception generally means how real human users feel or interpret the human surrogate. Commonly used measures of a real human's perceived "presence" with a surrogate include "social presence" and "co-presence." While there is no universal agreement on the definitions of these terms, for the purpose of this paper we consider *social presence* to be one's sense of being socially connected with the other, and *co-presence* to be one's sense of the other person's presence. In other words, social presence is more related to affective or emotional connections compared to co-presence [12]. Social influence is generally the change of one's attitude (e.g., emotions or behaviors) by others [3, 4], and in this human surrogate context, social influence may indicate how much a human surrogate can affect a real human users' attitudes. Since one's feeling of the surrogate would affect their emotions or behaviors, we can imply the causal relationship between one's perceptions of the human surrogate and the surrogate's social influence. This supports the importance of understanding human perceptions in human surrogate research related to its social influence.

In this paper, we address two common aspects related to the different forms of human surrogates: personal/interpersonal context and environmental context, and highlight some unique challenges

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and opportunities related to AH (compared to VH and RH) due to the nature of AR and human perceptions (e.g., social presence).

2 Human Surrogates in Social Interactions

2.1 Robotic Humans (RHs)

The concept of RH we consider is a physical humanoid robot that can mimic human appearance and behavior, and both perceive and affect real objects and the real environment. Some researchers have focused on human-robot interactions with these humanoid robots. Breazeal et. al. developed a socially intelligent robot (Leonardo) and demonstrated its learning capability from a real human's natural instructions [5]. Metta et. al. presented an open platform humanoid robot (iCub) [19], and many researchers have used the robot in their social interaction studies. For example, Fischer et. al. analyzed the verbal responses of human while varying the physical embodiment and degrees of freedom, and concluded both influenced human users' verbal behaviors [10]. In bi-directional telepresence, Nagendran et. al. used two humanoids for collaboration between remote human users, e.g., each humanoid was controlled by the other remote human user. They explored the robot's gestures, and the corresponding human users' sense of co-presence [21]. Some have tried to develop "androids" that have a flesh-like appearance similar to real humans. Ishiguro et. al. developed his own android robot and explored its effectiveness to understand the nature of real humans in general, in particular, personal aspects such as presence or personality traits [14].

2.2 Virtual Humans (VHs)

In contrast to RHs, VHs are computer-generated graphical humans, such as video game characters, so their existence is restricted to the virtual environment. In other words, although they can interact with real human users by displaying their expressions verbally or gesturally through display devices, real humans are aware of the spatial disconnect between the VH (in a virtual space) and themselves (in a real space). Some researchers in virtual reality have been trying to develop realistic VHs. Gratch and his colleagues have developed several VHs for military and medical applications, and explored many different aspects of the VHs including both technical improvements and human perceptions. Their "Simsensei Kiosk"—a VH interviewer for aiding in health care decisions—was a fully autonomous VH system that could recognize human user's verbal and nonverbal behaviors, e.g., natural language understanding and face detection (including gaze and expression recognition), and showed potential in face-to-face interactions [8]. Chuah et. al. also presented interactive VHs in a medical application [7]. They developed the VHs with a physical body (e.g., mannequin legs) and concluded that increasing the physicality of VHs could increase social presence. In educational training, Dieker et. al. employed the virtual environment system with VHs, called "TeachLivE" to train education students who planned to be teachers, and revealed its usefulness in teacher training [9]. Sagar et. al. introduced an autonomous animated VH face with high-fidelity of graphics and a neurobehavioral model for its realistic behaviors [24]. Hoque et. al. developed and used an interactive and expressive VH for interview training [13]. Their VH used multimodal information from the real human partner, such as verbal and nonverbal behaviors, and could generate appropriate responses in context. Some are interested in making avatar models of real humans. Lee et. al. presented the design of the development for their Lifelike Responsive Avatar Framework (LRAF), which used a virtual representation of a real human [16].

2.3 Augmented Humans (AHs)

As mentioned before, AH is basically the same as VH from a content perspective, but it can be distinguished from VH by the AR rendering and display technology. AR can render the AH as if it is in a real space by robust tracking and registration techniques. To differentiate AHs from VHs, here, we follow three conditions of AR that Azuma et. al. introduced: (i) it combines real and virtual objects in a real environment; (ii) it runs interactively in real time; and (iii) it registers (aligns) real and virtual object with each other (in 3D) [1]. There are many AR-related applications and research, but with respect to AH, the appears to be relatively little. One example is that of Jo et. al. who developed an AR tele-presence framework using an AH controlled by a remote user [15]. They discussed a problem of physical discrepancy between two locations in AH-based telepresence systems, e.g., the chair a user is sitting on can be different in shape and size from another chair his/her avatar should be sitting on in a remote location, which could reduce the AH's naturalism and realism. They tried to resolve the problem by matching virtual objects with remote real objects and using AH's motion adaption techniques so that they can maintain the AH's environmental plausibility. As a result, they presented better user responses in user experience and presence survey with their system.

3 Social Presence of Human Surrogates

As indicated above, we are defining *social presence* as how much real human users feel they are socially connected to the human surrogates, and *co-presence* as how much they feel that they are co-located with the surrogate. These concepts can be compared/correlated with a broader sense of *presence*—a sense of being together. Lombard and Ditton defined presence as the sense of *non-mediation*, which means that we can perceive presence via a technological medium if we can be totally oblivious to the existence of the medium [17]. MacIntyre et. al. addressed technical problems and contextual inconsistencies as discouragements of achieving the sense of non-mediation [18]. Technical problems normally include lack of computational power or accuracies, such as low-performance computing devices or inaccurate tracking in AR. Many researchers focus on such technical problems. For example, Feng et. al. focused on spatiotemporal inaccuracies in AR [31, 32]. Contextual inconsistencies are about a break of the realism of scenario, and sensory and behavioral aspects. Blascovich et. al. refer to "behavioral realism" as the "degree to which virtual humans and other objects within [immersive virtual environments] behave as they would in the physical world" [4]. Slater and his colleagues also emphasized sensorimotor contingencies and the credibility of the scenario in the same manner of consistency [26]. When the consistency fails, that could cause "break in presence" [23, 25]. In this sense, some evaluated human users' behaviors to measure presence in virtual reality [2, 11, 27]. One could say that a *negative expectancy violation* in social interactions[1], and the notion of an *"Uncanny Valley"* [20] could be related with the failure of the sense of non-mediation or contextual inconsistencies. Thus, for the higher sense of social presence (co-presence), this obliviousness to mediation should be considered to achieved as well. Harms and Biocca illustrated co-presence as one of dimensions that make up social presence, and they evaluated the validity of their social presence measures by questionnaire [12]. Measures of social presence (and co-presence) are an important part of understanding social influence of all three types of human surrogates: RHs, VHs, and AHs. Among many aspects of human perceptions, the reason why we only focus on social presence (co-presence) in this paper is because we believe that the sense of being together and connected is a fundamental and significant factor affecting one's emotions and behaviors in social interactions involving human surrogates.

4 Social Interactions in Context

We have considered the importance of social presence and some related aspects of technical problems/contextual inconsistencies for

[1] A negative expectancy violation is an unfavorable response due to the discrepancy between expected behaviors and enacted behaviors [6].

the sense of non-mediation. Here we describe two common aspects we think affect one's sense of social presence in social interactions with each type of human surrogate (RH, VH, and AH): *personal/interpersonal context* and *environmental context*.

4.1 Personal/Interpersonal Context

Personal context in social interactions with human surrogates is related to the real human user's individual knowledge or prior experience. For example, someone might have some understanding of how RHs, VHs, or AHs work technically, in which case their sense of social presence with the human surrogates may be lower than that of a novice. Likewise, someone's awareness of whether the surrogate is controlled by a human or an artificial agent may affect their sense of social presence. In many user studies with human surrogates, people try to reduce the influence of personal context by priming, e.g., via a "Wizard of Oz" paradigm.[2] In general, the personal context might be the same or similar for all three human surrogate types: RH, VH, and AH because personal context is in one's individual context rather than the surrogate's characteristics.

Interpersonal context is about communicational and emotional behaviors including both verbal and nonverbal cues between real human users and human surrogates. In human interactions, we have certain conventions of behaviors (e.g., social norms) although they could differ depending on cultural aspects; thus, we regulate and expect certain behaviors while we are interacting with each other. In the same manner, human surrogates should exhibit plausible social behaviors for their realism and social presence. Although there is a spatial difference between RH, VH, and AH, basic approaches to achieve plausible interpersonal context for each surrogate type could be similar or same in the aspects that we need to detect and recognize real human's behaviors or emotions.

4.2 Environmental Context

Environmental context is related to the physical/virtual environment that surrounds the real humans and the surrogates during the interactions. For example, an RH (or VH) can control or manipulate real (or virtual) objects in the environment. In environmental context, there can arise discrepancies between the human surrogate types because of the differences in their connectivities to the real world. For example, VHs and AHs cannot affect real objects physically in a physical space, while RHs can. We discuss such issues in terms of "Sensing" (awareness) and "Affecting" (influence), considering its difficulty of achievement (Table 1), and describe two sub-factors for each below.

- **Sensing**: i) *Mandatory*—A surrogate's basic sensing features are implemented for the purpose of its existence, e.g., safety. As an example, human surrogates have to sense the environment to avoid obstacles and dangerous events for protecting themselves and co-located human users. RH developers more likely consider this aspect because of RHs' physical presence compared to VHs and AHs. In VH's case, sensing environment is easily achieved because the developer creates all of the virtual environment. Since AHs are in a mixed space (middle of virtual and physical real spaces), AHs need to be aware of both the virtual and physical environments.

  ii) *Peripheral*—A surrogate's sensing features are implemented for additional reasons, such as understanding of social context or avoiding implausible behaviors. For example, human surrogates can sense room temperature to empathize with the feelings of the real humans. In social interactions, this "peripheral" sensing feature could be very important because it enables one to make a human surrogate's behavior more plausible from a social standpoint (context).

[2] In a *Wizard of Oz* paradigm a human subject is made to believe that a human surrogate behaves autonomously when it is controlled by a human.

Table 1: Level of difficulty to maintain contextual plausibility in environmental context (◯: relatively easy and possible, △: possible, but needs efforts, ×: difficult or impossible). VH is in a user-created virtual environment, so we already know the characteristics of the environment. For RH, sensing devices are needed to sense the physical environment, but RH's physical activities can naturally influence the physical environment without any treatment. AH also needs sensing devices to gather physical environmental data, but sophisticated control mechanism is additionally needed for AH to control/manipulate physical objects in the physical environment beyond AH itself.

Surrogate Type	**VH**	**RH**	**AH**
Environment	**Virtual**	**Physical**	**Mixed (Physical & Virtual)**
Sensing	◯	△	△
Affecting	◯	◯	×

- **Affecting**: i) *Surrogate to Environment*—A surrogate's ability to control/manipulate objects or to affect real human users physically in the environment. For example, a RH can grab a glass and move it to a different location. Both RH and VH can affect their own environment because they exists in corresponding spaces, i.e., RH in a physical space and VH in a virtual space. However, AH that exists in a mixed space can not really affect physical objects, and this disadvantage might negatively affect the sense of social presence of AHs because it can cause unexpected behavior.

  ii) *Environment to Surrogate*—A surrogate's ability to be influenced by the environment, including human users. For example, lighting conditions in a room will affect an RH's appearance (shading). Similar to the "Affecting (Surrogate to Environment)" factor above, RH and VH can be affected by environmental influences, but it is difficult if not impossible for an AH to be influenced by the environment, without special technical affordances—e.g., a "light probe" for proper environmental lighting of the AH. Improper or absent environmental influences on the AH can cause implausible situations.

4.3 Maintaining and Enhancing Presence

For each of the four environmental context factors described above, a common reason for including certain surrogate characteristics or behaviors is to *maintain* presence. In particular, the absence of certain characteristics or behavioral realism could give rise to contextual inconsistencies that result in a "break in presence" as discussed in Section 3. For example, a lack of environmental awareness (as indicated above) can consciously or sub-consciously break a sense of presence. However it is also possible that one would add/include certain surrogate characteristics or behaviors explicitly to *enhance* a sense of presence with a surrogate. For example, a surrogate might be able to target higher-level psychological processes related to social influence [4] by engaging the human in conversation that is focused on and self-relevant to the human, perhaps in a manner that conforms to their social identity.

5 Unique Challenges and Opportunities in AR

In Section 4.2 above we discussed four factors in environmental context that might affect one's sense of social presence by influencing contextual plausibility (Table 1). As indicated there are some unique challenges related to AHs, in particular due to the inability to control physical objects in the real space. Here we share some ideas for intentionally employing particular surrogate characteristics/behaviors as indicated in Section 4.3 that might simultaneously address the physical-control challenges while maintaining and perhaps even enhancing the sense of social/co-presence with the AHs.

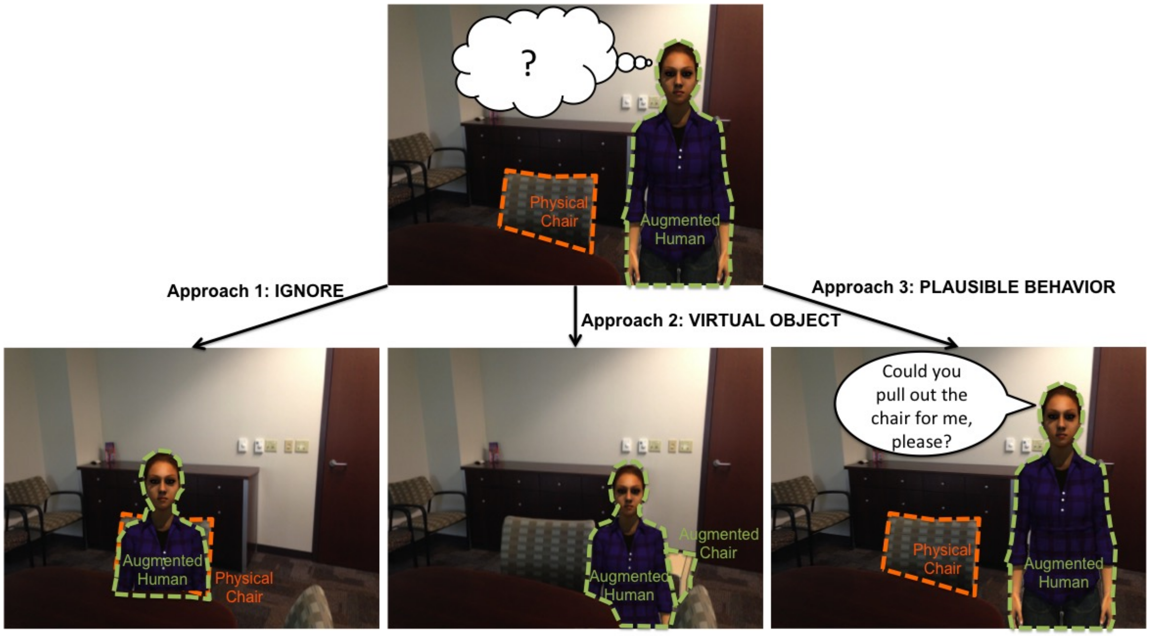

Figure 2: Top: AH cannot physically move the chair to sit on. Bottom-left: AH can ignore its limitation and be just overlaid in current physical setup. Bottom-center: Augmented object (chair) can be used to maintain the plausibility. Bottom-right: AH can ask a real human's help to move the chair, and this behavior could not only maintain the plausibility, but also perhaps enhance one's sense of social presence (co-presence) of the AH.

First, as we mentioned before, an AH (in AR) allows for a seamless visual connection between the real and virtual worlds, which can be a good chance to deceive human user's belief of AH's authenticity (realism) in terms of personal context (Section 4.1). For example, Suzuki et. al. presented a substitutional reality platform using panoramic imagery, which could muddle real human subject's awareness of reality and recorded videos [29], and in the same manner, Steptoe et. al. developed an AR environment, which could make it difficult to distinguish virtual from real objects using non-photorealistic imagery [28]. Using such techniques one might be able to make people believe that an AH is a real human, so that they can feel higher sense of social presence with the AH.

However, this benefit of seamless connection in AR with a real space could cause unique challenges as well. In particular, with respect to environmental context, real human users might perceive that the AH is necessarily able to do physical activities with real humans and environment. When they observe that the AH cannot perform physical activities, or worse—if it "disobeys" the norms of physical activities, their sense of social presence of the AH might be harmed. This means AH's behaviors are limited by current state of physical environment in order to maintain the plausibility of the AH's existence in that environment. As an example, imagine that AH needs to sit on a chair under a desk. In a plausible environmental context, AH should pull out the chair and sit on it, which AH cannot do. There might be several approaches that deal with this problem (Figure 2).

- **IGNORE**: One might just accept the limitation (any physical-virtual mismatch) of AH, so they just ignore the physicality, e.g., AH passes through the chair. However, as we indicated before, this can cause a "break in presence" or negative expectancy violation and harm one's sense of social presence.

- **VIRTUAL OBJECT**: To resolve the limitation without hurting one's sense of social presence, one might want to use additional virtual objects. For example, if AH is able to use a virtual chair in AR environment, the AH can pull and sit on the virtual chair as opposed to trying to sit in a real/physical chair. If it is not available because of any physical limitations, such as lack of physical space to render a virtual chair, we might want to erase the physical chair on display and render a virtual chair on the same spot (i.e., diminished and augmented reality). In this way, we might be able to maintain the sense of social presence.

- **PLAUSIBLE BEHAVIOR**: The last approach we want to highlight is a way to simultaneously avoid implausible situations and enhance one's sense of social presence by AH's plausible behaviors in context. For example, AH can ask help from real humans to alter physical environment without revealing its functional deficiency, e.g., the AH might ask co-located real humans to pull out the chair. In this way, the limitation of physical connection with AH might also present an opportunity that people might perceive AH's engagement in the interaction.

The first two approaches can be generalized to any augmented objects (even beyond AHs) because the approaches are based on either ignoring the problem or resolving it by replacing the problematic objects. However, the last approach (plausible behaviors) is only possible in human surrogate environments because such environments involve more social/psychological aspects of human behaviors. In other words, we should study and understand what kind of human behaviors are appropriate in what situation, and how those behaviors affect human perceptions. Besides, there is an important aspect that we can take an opportunity intentionally reinforcing social presence by expressing AH's proactivity beyond preserving social presence by not hurting contextual plausibility.

6 Conclusion

Technology-based human surrogates (e.g., virtual humans or humanoid robots) have been growing in popularity due to their current and potential usefulness in our lives. In this paper, we described some characteristics of RH, VH, and AH comparing social interactions of each surrogate type in context. We identified certain unique aspects of AH due to the nature of AR technology, e.g., visually seamless connection between AH and physical environment including real humans. Although these unique aspects of AH provide some benefits increasing visual plausibility, this uniqueness could also become a downside (challenge) because of AH's inability to influence the physical environment. In short, AH is not able to be physically influenced by real (physical) environment, or to control physical things in a real space. This challenge could be critical to maintain or destroy AH's realism and one's sense of social presence of the AH. In this sense, we addressed possible approaches to deal with these limitations of AH, and highlighted the opportunity that can maintain contextual consistency and reinforce social presence by a non-technical approach such as AH's appropriate behaviors in the context. While pursuing technical achievement of AH, we might have to think of how the AH can affect physical environment or get affected by the environment while preserving the contextual consistency and effectiveness of AH.

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