Incorporating Virtuality in Ubiquitous Computing Services for Influencing Human Behavior

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***Abstract*—The role of computing technologies has been expanding, and our lifestyles will be significantly influenced by these technologies. Refining the meaning of real space by incorporating virtuality through ubiquitous computing technologies is a very powerful concept because people's senses are enhanced, making them potentially see something that may not exist in the real space. For example, human eyesight can be altered using head-mounted displays, which modify real-world views captured by video cameras with mixed reality technologies. These approaches are also useful in influencing human behaviors that make a variety of new types of digital services possible. The paper presents four case studies to enhance the meaning of the real space through incorporating virtuality and proposes a design guideline extracted from the experience with their development.**

Keywords-Ubiquitous Computing; Mixed Reality; Virtual Reality; Augmented Reality; Virtuality; Head-Mounted Display;

I. INTRODUCTION

Ubiquitous computing technologies allow us to refine the meaning of our real space through incorporating virtuality for influencing our behaviors [12][20][25]. For example, recent advanced technologies, such as a Magic Leap's technology [9] and Microsoft HoloLens [10], can easily refine the meaning of our real space and offer new possibilities to change our daily lifestyle. For example, human eyesight can be altered using head-mounted displays (HMDs), which modify real-world views captured by video cameras with mixed reality technologies. For our daily life to become more sustainable and well-being, behavior changes are essential [12][24]. To alter our behaviors, the meaning of the real space must be refined through incorporating virtuality to make people believe that their changes have meaningful effects on our future and environments. However, there are very few researches on design strategies to refine the meaning of the real space through incorporating virtuality because such researches must take into account multiple different disciplines that are typically distinguished, and substantial effort is required to integrate them. For example, significant movie and animation content exploits virtuality to influence our daily behaviors; however, the discussions about design content would rather be isolated from the technology design of digital services, although ubiquitous computing technologies are essentially virtualizing our daily lives [3]. Therefore, although technology has sufficiently advanced, it is difficult to discuss how to guide the design of the refined real space valuably and meaningfully.

In this paper, our focus is to investigate a design guideline to examine the quality of virtuality. Existing researches have shown some design guidelines for developing augmented reality and virtual reality services. However, their focuses are to offer design guidelines to develop augmented reality services or to examine the quality of virtuality in virtual spaces, and there are no good metrics to extract potential pitfalls of the quality of virtuality incorporated in real spaces. For extracting the guideline, we first present four case studies to enhance the meaning of the real space through incorporating virtuality. By incorporating virtuality that does not exist in the real space that we currently see, our behaviors can be influenced then altered [8][13][19][20][22][24][25]. The aims to develop these case studies have exploited to incorporate virtuality in our daily real life, and these case studies incorporate virtuality from diverse angles. Thus, they are appropriate to extract a guideline for designing virtuality embedded in real spaces. We then present a guideline extracted from the experience with their developments. Because the guideline focuses on the design of incorporated virtuality in real spaces, and finds potential pitfalls of the design; thus, it can complement other existing guidelines.

This paper is organized as follows. Section II presents some related work on this study. In Section III, we describe four case studies, and show a design guideline extracted from the experiences with building the case studies in Section IV. Finally, Section V concludes the paper.

II. RELATED WORK

Several existing services examine the use of augmented reality technologies to enhance the meaning of real space to influence people's attitudes and behaviors. For example, in [5], the authors reported on the concept of *Blended Virtuality*, whereby people use HMDs while downhill skiing and snowboarding. The user experiences a visually enhanced real space through the HMD without losing the full sensation of real-world skiing. In [13], the authors propose a service that using augmented reality technologies to implicitly influence the satisfaction that people experience when drinking a beverage and to control beverage consumption by creating a volume perception illusion. The system proposed in [22] aims to use augmented reality technologies as a way of modifying perceptions of satiety to control nutritional intake by

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changing the apparent size of food. In [25], several case studies to offer playful augmented reality applications that seamlessly integrate virtuality in real space are reported.

There are several researches to propose guidelines to develop services incorporating virtuality. For example, in [16], the authors present a guideline for the development process of mobile augmented reality applications. Also, in [23], some useful guidelines to develop better augmented reality games are described. In [25], the authors present guidelines to make traditional games more enjoyable by incorporating virtuality. These guidelines focus on how to develop services and applications to incorporate virtuarity in them, and they do not focus on the effective ways to design the quality of virtuality. Some other frameworks are also useful to help the design of virtuality from different angles. For example, the framework described in [18] shows some properties for designing meaningful virtuality. Also, in [20], the framework to categorize the type of virtuality is proposed.

However, currently, there are no sufficient discussions how to maintain the quality of incorporated virtuality in the real space. Although the approach is promising, but there is no proper design guidelines for designing virtuality used in real spaces in terms of the quality. The quality of virtuality is essential because a user does not want to use services that he/she feels a sense of incongruity in the incorporated virtuality in real spaces.

III. FOUR CASE STUDIES

A. *HoloMoL: Human Memory Augmentation with Mixed-Reality Technologies*

HoloLens, Microsoft's HMD, has recently attracted people to develop new services in a variety of fields. Microsoft HoloLens [10] is able to deliver a mixed reality user experience [1], allowing people to interact with virtual objects and entities within real world settings. Mixed reality technologies enable designers to develop new types of advanced services that incorporating virtuality into the real world. The software platform that accompanies the Microsoft HoloLens hardware enabled developing mixed reality applications easily without requiring advanced skills. Various visions of possible novel services have already been presented. We would like to investigate supporting memorization techniques as a new application domain for Microsoft HoloLens, where we adopt the method of loci which is an ancient Greek method that can be used to memorize different types of information [26]. The first case study is named *HoloMoL* (HoloLens's Method of Loci).

The main objective of *HoloMoL* is to support the method of loci for augmenting human memory with mixed reality technologies based on Microsoft HoloLens and to enable utilizing the method of loci with minimal training. The original method of loci enables people to memorize information by imagining a space in their mind and placing information in the such space. *HoloMoL* replaces the imaginary space with real world places that people also know well. *HoloMoL* automatically lays out information, that people intend to memorize, as AR entities within a real space. Thus, they experience the method of loci by moving in the real space, where corresponding information is automatically displayed using *HoloMoL*, so they are able to memorize the information as they navigate through the space.

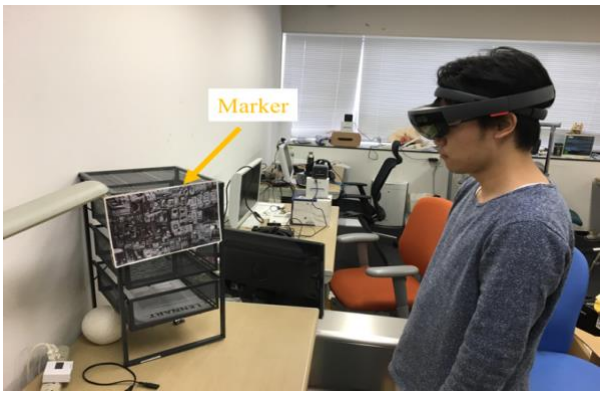

Figure 1. A user places a fiducial marker in his preferred location in a real space for memorizing information

Figure 2. A user places respective fiducial makers that correspond to information to be memorized in difference places

HoloMoL provide the ability to display the corresponding information using mixed reality technologies when a person gazes at a specific position in a real space. When a person wears a Microsoft HoloLens device, the surroundings that are normally visible are the same as the actual view, but when he/she moves to a position specified by him/her in advance and recognizes a specific marker, the corresponding information is automatically displayed.

Our implementation utilizes fiducial markers to lay out various information registered to the real space as shown in Figures 1 and 2. Since *MoloMoL*'s objective is to investigate how people would place information for memorization, we decided to use printed fiducial markers that people were able to physically move and place around the environment. By placing a marker near any objects located in a real space, *HoloMoL* exploits associative memory to memorize a variety of information.

The current version of *HoloMoL* is developed as an application of Microsoft HoloLens. Unity is used as a software platform to render 3D contents in the real space, and Vuforia is adopted to recognize fiducial markers. The

database implemented in *HoloMoL* associates the image of each marker to be recognized with the corresponding information to be displayed in the real space. When a marker is recognized, the database is referenced, and the corresponding information is displayed as a sequence of characters written on a plate-shaped object as shown in Figure 2.

B. *AmbientBot: Delivering Daily Casual Information through Eye Contact with an Intimate Virtual Creature*

Our daily life becomes increasingly rich through the progress of advanced digital technologies. In particular, our modern daily lifestyle has been dramatically changed because of smart phones that always connect us to the Internet, thus enabling access to various information sources anytime and anywhere. However, the current progress of information technologies significantly increases our cognitive overload. In our daily commute in Tokyo, for example, a tremendous amount of information is presented to us through public displays located in trains and stations. As shown in [15], various modern social media try to steal our available attention by using ubiquitous computing technologies. For making our daily life more comfortable and peaceful, information should be more ambiently and intimately delivered to us only when the information is really necessary. In addition, the information should be available to us without extra time and effort.

Figure 3. Ambient Bot Concept

The second case study, called *Ambient Bot*, presents an intimate virtual creature in the real space with augmented reality technologies. *Ambient Bot* arranges a virtual creature in a user' view as shown in Figure 3, but the creature leaves the user's scope when he/she does not want to receive any information from the creature. If some information wants to be received when becoming free, he/she tries to find the virtual creature in his/her current view.

When focusing his/her attention on the creature, it speaks and visualizes information to him/her, but when turning his/her attention away from the creature, it stops speaking. Therefore, the creature always but ambiently exists in the user's view, but does not disturb his/her current activities when not focusing his/her attention on the creature. *Ambient Bot* offers information in a social manner because the user feels an intimate relationship with the creature [17]; thus, the interaction with the creature will make his/her daily life richer [18], unlike traditional notification technologies that focus on only the efficiency through functionalism that sometimes offers tasteless interaction. Especially, for Japanese young adults who are very familiar with various anime and video game products, using intimate virtual creatures not highly functional inorganic products makes them feel more social and intimate relationship with advanced information technologies.

Ambient Bot shown in Figure 4 currently displays a jellyfish as a virtual creature in a user's surrounding space with augmented reality technologies, and the jellyfish speaks to the user when he makes eye contact with the jellyfish. He uses the prototype system by wearing an HMD; Oculus Rift is currently chosen as the HMD for *Ambient Bot*. As described in the previous section, we chose the latest news articles, weather forecast, or latest posts or trending words in a social media service were chosen as the content that the jellyfish speaks. In Figure 4, the left photo shows a user who wears an HMD for using Ambient Bot, and the center photo is a view that he actually sees the view through the HMD. When he makes eye contact with the jellyfish, the jellyfish turns to him, then speaks and presents appropriate contents to him. The content is retrieved from the Google News API, the LINE's WeatherHacks API, and the Twitter API. The content is converted into voice data through the Hoya's VoiceText Web API for the jellyfish to speak. The content is also shown on a user's HMD in real time when the jellyfish speaks the content.

C. *Augmented Bike: Building a Platform Society towards Sustainability*

This section presents the third case study named *Augmented Bike* for designing a social platform towards environmental sustainability based on Internet-of-Things. The case study we investigate encourages low carbon communities [6][7], in particular, to aim for a car-free city. A car-free city promises to make our society more sustainable [4]; however, people must be guided to choose a desirable lifestyle. *Augmented Bike* is an Internet of Things (IoT)-enhanced bicycle for promoting bicycle-sharing within communities. Bicycle sharing can help to achieve a car-free city, and IoT-based daily artifacts can contribute to building an effective social platform.

Augmented Bike is a digitally enhanced daily artifact that augments rental bicycles using VR and AR technologies. When a new wearable device such as Google Glass becomes popular and most people wear the device in the near future, the devices can be used for facilitating a car-free city by augmenting rental bicycles with the new wearable devices and motivating people to use a rental bicycle. Using an *Augmented Bike*, people can easily rent a bike by touching their IC cards or using a fingerprint or an implanted IC chip that contains their personal information. Let us imagine a situation in which people always use an HMD and the display does not impede their sight, unlike a current HMD such as Oculus Lift. *Augmented Bike* as

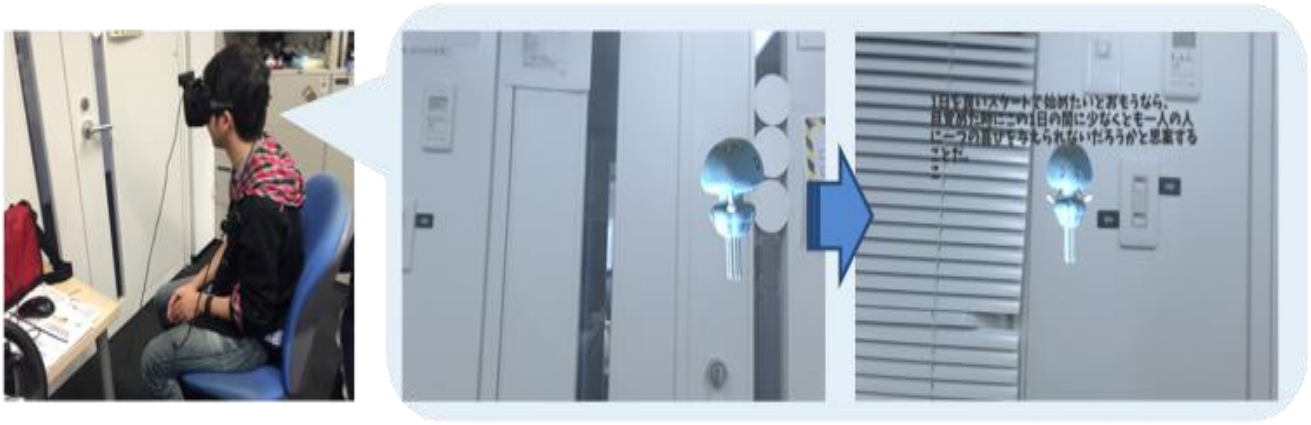

Figure 4. An Ambient Bot System

shown in Figure 5 enhances people's view and shows additional information on the HMDs that they wear. In addition, traveling distance and trail information are recorded on their smartphones, and people can check the information anytime. Figure 5 presents an overview of the *Augmented Bike* prototype.

When using the *Augmented Bike*, an application program displays the images that enhance a user's current real view on an HMD and shows pop-up information regarding the images to provide the rider with additional information. We also developed an application program that records traveling distance and trail information, and we offer some gamification effects using graphical changes.

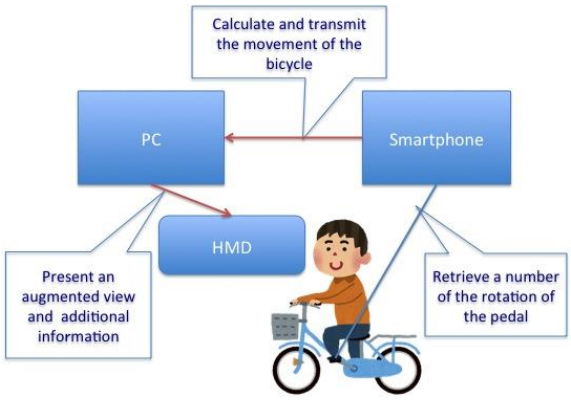

Figure 5. Augmented Bike Concept

The current *Augmented Bike* shown in Figure 6 uses Oculus Rift as an HMD. In a typical case, the video that is captured from the real world by a camera attached to Oculus Rift is shown to a user so that the user can use his eyes to see his surroundings and simultaneously see virtual scenes generated by virtual reality technology. The current prototype identifies a user by fingerprints taken before and after using the *Augmented Bike*. In addition, a smartphone application runs on Android OS, and we use Unity as a platform to execute our applications both for Oculus Lift and the smartphone. The programs are written in C# and use Node.js to communicate between two application programs. The smartphone application monitors the movement of the pedals of the *Augmented Bike* using an acceleration sensor and transmits the information to a PC. The program running on the PC generates images to Oculus Lift. Our current prototype must use a desktop PC now although the prototype will work on a more powerful smartphone in the near future.

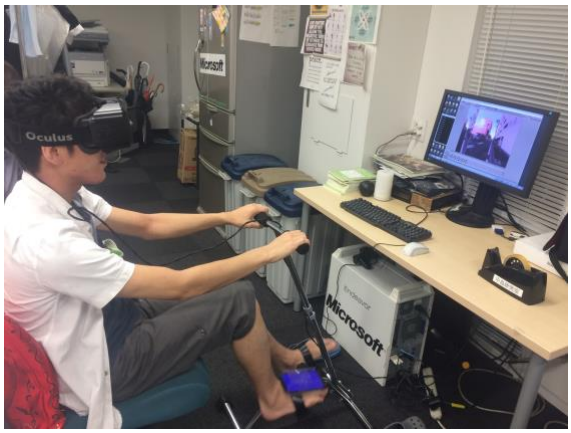

Figure 6. An Experiment Using the Augmented Bike

D. Mindful Reminder: Increasing a User's Empathy toward His/Her Surrounding Environment

At present, various useful digital services already enrich people's daily lives. For example, sharing economy services and social networking services have become popular. These services allow us communicate with other people in a new and different way, making human relationships more meaningful. These relationships make us more mindful of various aspects of our daily lives because these services exploit new opportunities to enhance serendipitous human relationships. However, our modern daily lives increasingly busy, and we sometimes forget to empathize with other people, even though emerging digital services facilitate human relationships. In particular, information technologies provide various notifications to keep the user mindful and calm, thereby reducing the overextension of human cognitive resources and using those resources more effectively [2]. However, current notification technologies

exploit peripheral attention and make our daily lives inorganic because such notifications do not facilitate human relationships.

Thus, the effect of these notification services is not strong enough to make people's lives really flourish. Of course, many digital services already notify us about important issues in our daily lives; for example, a calendar service notifies a person about his/her schedule, and a reminder service tells him/her what he/she needs to do. However, the information is typically sent through smartphones or laptops; thus, although the services increase the richness of our daily lives in terms of efficiency, we flourish less in our daily lives and forget about people's feelings and empathy, which is important to make our daily lives mindful and calm when the number of notifications increases.

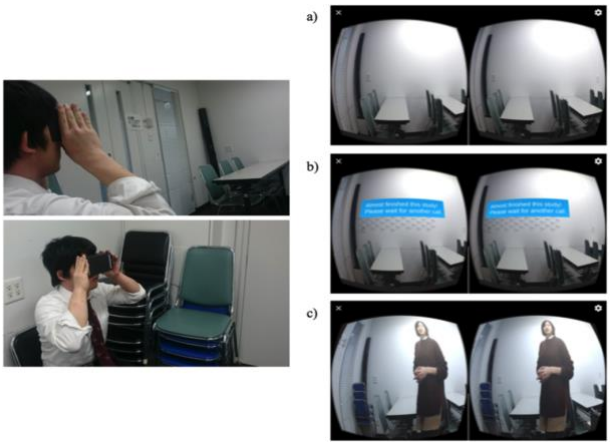

Figure 7. An Overview of Mindful Reminder

By contrast, notifying a user about a particular issue through a narrative delivered by human, particularly a real human who is close to the user—not a device—makes our lives flourish more because the notification explores human relationships and makes us aware of people's empathy. We call notifications that make the user empathize others and that increase the flourishing of his/her daily life *mindful notifications*, which may provide the user with an opportunity to feel grateful for someone else and to be aware of their hospitality. *Mindful Reminder* is the fourth case study that offers mindful notifications to the user. *Mindful Reminder* aims to help the user overcome many problems in his/her daily life. For instance, it reminds the user of his/her schedule, displays information or prevents the user from forgetting objects. These mindful notifications are provided by a virtual human; they are not inorganic notifications from peripheral environments. Of course, the use of mindful and calm notifications entails a tradeoff with regard to human cognitive overload. As shown in [14], this balance is important to effectively increase the influence on the user's daily behavior through notifications via the tradeoff between his/her cognitive overload and the promotion of human relationships.

With *Mindful Reminder*, a virtual human who represents a real acquaintance of the user delivers mindful notifications. Notifications are virtualized based on the Alternative Reality concept [8]; thus, a user does not notice that the real acquaintance is not the virtual human; thus, the user believes that the notification is delivered from the real acquaintance who notifies him/her. When using *Mindful Reminder*, the user wears an HMD and the virtualized acquaintances are displayed in real space (see Figure 7). The Alternative Reality concept makes it possible to seamlessly blend virtuality into the real world. The virtualized acquaintance and the contents of the notification are chosen according to the current real location and situation of the user. Figure 8 (a) shows a typical situation in *Mindful Reminder*, where a virtualized acquaintance talks about a user's umbrella, which he/she brings with him/her on the train that he/she is riding on. Figure 8 (b) shows another example in which a shop assistant informs the user about how to stay in the café, and Figure 8 c) depicts when a user's friend talks about the class that he/she is taking in his/her school.

Two key issues are essential when designing *Mindful Reminder*. The first issue concerns the appropriate virtualized acquaintance delivering the correct information based on the user's current situation. The context awareness of the service allows us to naturally integrate a mindful notification into the real world. The second issue relates to when a user cannot recognize the difference between the real acquaintance and the virtualized acquaintance. If the user knows that the notification is delivered by a system instead of a human, the notification will not trigger an empathetic reaction from the user. The user needs to believe that the virtualized acquaintance is a real acquaintance and to be aware of the acquaintance's hospitality; the user will thus become aware of other people's hospitality toward him/her.

IV. EXPLORING DESIGN SPACE FOR DESIGNING REALITY

The guideline that we propose in this section complements the potential pitfall to incorporate virtuality in the real space based on the concept of the *magic circle* [11]. This concept has been developed to discuss the boundaries between the real space and the virtual space in video games. An expert who have designed and developed the case studies mainly charged a process to derive the guideline because he was also involved into the design and the evaluation of all case studies. The expert analysis is promising to derive abstract design knowledge. In the compiling process to extract the guideline, he generalizes and structures the ad-hoc design process to develop the case studies based on his observations. The development of the guideline was evolved in an iterated way until he had confidence that the guideline become sufficiently mature.

The proposed guideline considers that the following three levels of the magic circle are classified. The first one is the *individual magic circle*, where only one person who is a stakeholder of a service can feel the reality of an incorporated virtual value in a dimension. The second one is the *community magic circle*, where people who are members of a community as stakeholders of a service can feel the reality of an incorporated virtual value in the real space, but other people who are not the members of the

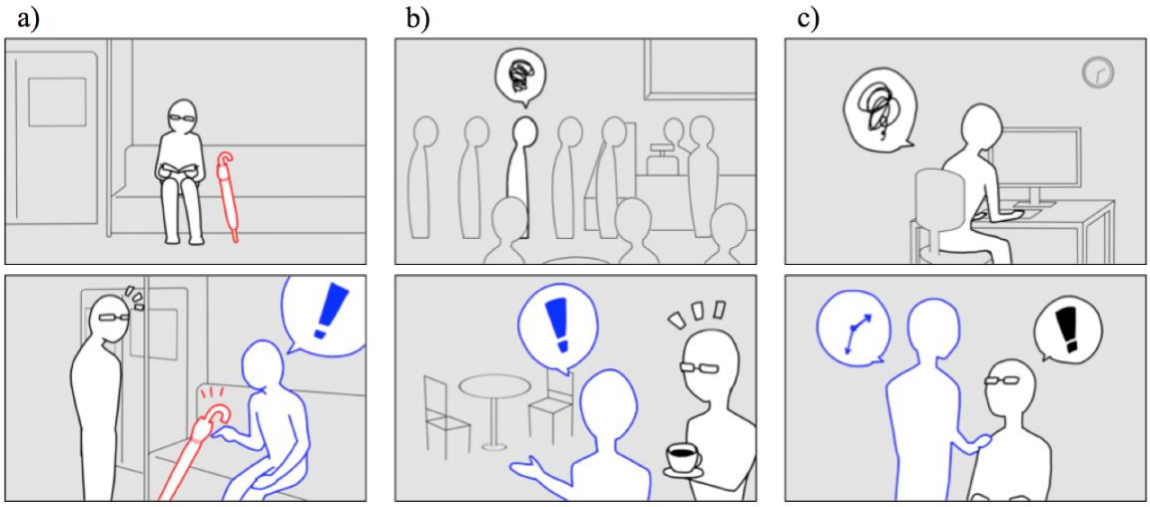

Figure 8. Illustrations of the scenarios in Mindful Reminder

community may not feel this reality. Finally, the third magic circle is the *universal magic circle*, where all people as stakeholders of a service feel the reality of an incorporated virtual value in the real space; thus, the magic circle disappears for them. These levels are crucial when considering the stakeholders in a ubiquitous computing service that incorporates virtuality, e.g., those who can sense the reality of an element in each dimension. For example, the point is frequently used in typical video games, and it can be used to strengthen a player's abilities in the game within the individual magic circle. However, the point can be usually exchanged within the game in the community magic circle, and the effect of the point is extended to most players in the game. Finally, the point can be exchanged for real money within the universal magic circle, and the effect of the point can be extended to all people.

When designing or analyzing a digital service, the levels of the magic circle become an important criterion for defining the boundaries between the real and the virtual. In particular, analyzing the levels of the service is critical when discussing the quality of the virtuality because the boundaries between the real and the virtual should be consistent among the stakeholders in the service. If a stakeholder involved in the service does not sense the reality of some of the incorporated virtual values in a dimension, incorporated virtuality has failed to affect them because the consistency among stakeholders is broken and the misunderstanding caused by the inconsistency significantly reduces the quality of the service. However, the universal magic circle is difficult to achieve because people who may not be involved in the service need to believe in the reality of some incorporated virtual values. Thus, the three levels proposed in the guideline are useful when analyzing the balance of the reality of incorporated virtuality in the digital service and the tradeoff in choosing the level.

For example, when *HoloMoL* is used by multiple users, they should see the same augmented information on the same real space if they are collaborating together. Also, in *Ambient Bot*, when a user looks at a virtual creature, other people should be aware what the user is looking at. In *Augmented Bike*, a user needs to see other bikes and pedestrians because even the user drives his/her bike in the virtual space to maintain the safety. In *Mindful Reminder*, a user's friend should be aware of the existence of the virtual persons who gives the user notifications.

From our experiences with building the four case studies described in Section III, we found that designers typically consider only individual magic circles based on their own past experiences. Therefore, in their user studies, their participants failed to understand the meaning of virtuality intended by the designers. One of important insights extracted from the discussions is that participatory design [21] is a useful tool to overcome the potential pitfalls to offer community magic circle or universal magic circle. If users who have various backgrounds are involved in the design of virtuality, the meaning of the virtuality can become understandable by them. The guideline presented in the section lets designers who develop ubiquitous computing services that incorporate virtuality to consider who are stakeholders of the services and how virtuality should be seen by these stakeholders.

Different from other guidelines and frameworks described in Section II, our framework offers design frames that allow service designers to focus on the plausibility of incorporated virtuality in the services that they develop. Especially, one important aspect of the proposed guideline is to allow service designers to explicitly take into account multiple stakeholders appeared in the services. Then, the framework is useful to find some potential pitfalls that are not easy to be extracted by other existing guidelines and frameworks.

V. Conclusion and Future Direction

The paper presented four case studies that refine the meaning of the real space through incorporated virtuality. The case studies use HMDs to refine a user' view to include

virtuality in the real space. Since the refined view significantly influences a user's behavior, the approach offers promising possibilities to develop various new services. However, as shown in Section IV, the reality needs to be properly designed in terms of who are stakeholders of the services. In particular, the services may lose the usefulness if some of stakeholders are not aware of the meaning of incorporated virtuality in an adequate manner.

The aim of this paper is to extract an effective guideline to design virtuaity from the case studies that we have developed. We hope that the guideline is useful to extract some potential pitfalls that existing guidelines and frameworks could not find easily. However, we still need to validate the proposed guideline in developing new case studies. In particular, we will plan to report actual potential pitfalls when designing the new case studies through participatory design with the proposed guideline. In the participatory design, participants will play roles of respective stakeholders in them, and discuss the meaning of incorporated virtuality from each stakeholder's angle.

REFERENCES

[1] Accenture Technology, "Mixed reality brings real benefits to enterprises", https://www.accenture.com/us-en/insight-real-benefits-mixed-reality-brings-enterprise, [retrieved: December 2017]

[2] S. Bakker and K. Niemantsverdriet, "The Interaction-Attention Continuum: Considering Various Levels of Human Attention in Interaction Design", International Journal of Design, Vol. 10, No. 2, 2016, pp.1-14.

[3] J. Baudrillard, "The Consumer Society: Myths and Structures", Sage Publications Ltd., 1998

[4] J.H. Crawford, "Carfree Cities", Intl Books, 2000

[5] A. Colley, J. Väyrynen, and J. Häkkilä, "Skiing in a blended virtuality: an in-the-wild experiment", In Proceeding of the 19th International Academic Mindtrek Conference, 2005, pp.89-91.

[6] H. Fraker, "The Hidden Potential of Sustainable Neighborhoods: Lessons from Low-Carbon Communities", Island Press, 2013

[7] N. Foletta and J. Henderson, Low Car(bon) Communities: Inspiring Car-free and Car-lite Urban Futures, Routledge, 2016

[8] F. Ishizawa and T. Nakajima, "Alternative Reality: An Augmented Daily Urban World Inserting Virtual Scenes Temporally", In Proceeding of the 10th International Conference on Ubiquitous Computing, 2016, pp.353-364.

[9] Magic Leap, https://www.magicleap.com/ [retrieved: December 2017]

[10] Microsoft HoloLens, https://www.microsoft.com/microsoft-hololens/ [retrieved: December 2017]

[11] M. Montola, J. Stemros, and A. Waern, "Pervasive Games - Theory and Design", Morgan Kaufmann, 2009.

[12] T. Nakajima and V. Lehdonvirta, "Designing Motivation in Persuasive Ambient Mirrors", Personal and Ubiquitous Computing, Vol. 17, No.1, Springer Verlag, 2013, pp.107-126.

[13] T. Narumi, Y. Ban, T. Kajinami, T. Tanikawa, and M. Hirose, "Augmented Perception of Satiety: Controlling Food Consumption by Changing Apparent Size of Food with Augmented Reality", In Proceedings of the Conference on Human Factors in Computing Systems, 2012, pp.109-118.

[14] K. Niedderer, et al., "Design for Behaviour Change as a Driver for Sustainable Innovation: Challenges and Opportunities for Implementation in the Private and Public Sectors", International Journal of Design, Vol. 10, No. 2, 2016, pp.67-85

[15] T. Okoshi, K. Tsubouchi, M. Taji, T. Ichikawa, and H. Tokuda, "Attention and Engagement-Awareness in the Wild: A Large-Scale Study with Adaptive Notifications", In Proceedings of the International Conference on Pervasive Computing and Communications, IEEE, 2017, pp.100-110.

[16] M. de Sá and E. Churchill, "Mobile augmented reality: exploring design and prototyping techniques", In Proceedings of the 14th international conference on Human-computer interaction with mobile devices and services, 2012, pp.221-230.

[17] M. Sakamoto, T. Alexandrova, and T. Nakajima, "Introducing virtuality to enhance game-related physical artifacts", International Journal of Smart Home, Vol. 8, No. 2, 2014, pp.137-152.

[18] M. Sakamoto, T. Nakajima, and T. Alexandrova, "Enhancing Values through Virtuality for Intelligent Artifacts that Influence Human Attitude and Behavior", Multimedia Tools and Applications, Springer, Vol. 74, No. 24, Springer Verlag, 2015, pp. 11537–11568

[19] M. Sakamoto and T. Nakajima, "Making Citizens' Activities Flourish through a Crowdsourcing-based Social Infrastructure", In Konomi. S., Rousso, G., (eds.) Enriching Urban Spaces with Ambient Computing, the Internet of Things, and Smart City Design, IGI Global, 2016, pp.232-255.

[20] M. Sakamoto, T. Nakajima, and S. Akioka, "Gamifying Collective Human Behavior with Gameful Digital Rhetoric", Multimedia Tools and Applications, Vol.76, No.10, Springer Verlag, 2017, pp.12539–12581

[21] D. Schuler and A. Namioka, "Participatory Design: Principles and Practices", CRC Press, 1993.

[22] E. Suzuki, T. Narumi, S. Sakurai, T. Tanikawa, and M. Hirose, "Illusion Cup: Interactive Controlling of Beverage Consumption Based on an Illusion of Volume Perception", In Proceedings of the 5th Augmented Human International Conference, 2014, Article No.41.

[23] R. Wetzel, R. McCall, A-K. Braun, and W. Broll, "Guidelines for designing augmented reality games", In Proceedings of the 2008 Conference on Future Play: Research, Play, Share, 2008.

[24] A.K. Wolfe, E.L. Malone, J. Heerwagen, and J. Dion, "Behavioral Change and Building Performance: Strategies for Significant, Persistent, and Measurable Institutional Change", US Department of Energy, 2014

[25] T. Yamabe and T. Nakajima, "Playful Training with Augmented Reality Games: Case Studies Toward Reality-oriented System Design". Multimedia Tools and Application, Vol.62, No.1, Springer Verlag, 2013, pp.259–286.

[26] F.A. Yates, "The Art of Memory", Bodley Head, 2014.