Principles of Dynamic Display Aiding Presence in Mixed Reality Space Design

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Abstract. In this study, presence principles were developed for dynamic display design and evaluation of dynamic display for designing mixed reality space. This is a research to classify the indicators collected through the researches about the existing measurement and evaluation of the existence felling and information suggestion methods in mixed reality as the evaluation principles of the displays and multimodal's interfaces that construct the mixed reality. Additionally, by constructing QFD evaluation frame based on this presence principles and evaluating the interface that composes the mixed reality, research results were tried to be reflected in the future works.

Keywords: Spatial Presence, Dynamic Display, Mixed Reality, Presence Principles.

1 Introduction

According to Milgram(1999), MR space is where Real Components and Virtual Components are mixed together. Spatial characteristics are assigned within the range of Reality-Virtuality Continuum according to the occupation percentage of real component and virtual component environment, as well as whether the environment displaying the component is virtual or real [1]. This MR is an AR that creates overlap in virtual information with reality, or a form of VR that substitutes reality in altering the real space [8]. Accordingly, our Real World, in other words, elements that form the space with the existing static characteristics(wall, furniture, lighting and etc.) are absorbed into the components of the digitalized space and possess variable characteristic, and physical characteristics change to non-physical characteristics as well as others and thus mixed realitization can be expected [11]. There are various applications under research, which introduces MR space. In particular, early AR-related technologies were developed and studied for use with industry, military readiness, surgery training, computer games, and computer-supported collaboration. Research on AR-related technology is ongoing as the spread of small handheld devices and smartphones increases [8].

However, the current state of the matter is that if a task is performed in these MR spaces, the sense of presence and the sense of immersion from the virtual components projected in a manner of image, which the user feels, is lower than that of the physical feedback received from real components. In many research, it is stated that in order to

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overcome the lack of sense of presence, the MR environment must be similar to that of the actual physical environment[2]. Therefore, acquiring sense of presence and sense of immersion is a core objective in MR environment construction that supports effective interaction.

Heeter(1992) classifies the sense of presence into three different types, including Personal, Social, and Environmental[10]. Looking closely at research that increases sense of presence, centering around Environmental Presence which is closely related to MR space, we can classify the research field into two broad categories including data processing and interface field. In non-preprocess fields, 3d information modeling, dynamic information visualization methods among other solutions are used to increase visual reality, or research which allows for user context, usability among others in applying methodology in visualization of information that does not interfere with immersion in acquiring sense of presence, and there has also been research carried out using the method of supplementing the lack of sensory elements by providing other senses along with TUI, OUI, NUI, tactile interface and etc, as a way of expanding and supplementing sensory factor concentrated on the visualization of current GUI for the research in the interface field for MR presentation.

In order to design dynamic interface for MR presentation, a GUI and complementary, integrated interface concept model is necessary as opposed to the method of complete substitution of GUI. Furthermore, from the system aspect, it must not limit the systematic, cognitive, intelligent transform to only the types or forms of information, but rather expand out to interface search, assignment issues that can best support the modified form.

The contributions of this paper can be summarized as follows:

- ***Develop dynamic display principles for MR space design based on criteria of presence.*** All of the researches up to this point, have suggested principles based on factors covering the sense of presence in general. However, in this research, we have classified factors related to space and interface among the factors related to sense of presence, in order for new concept dynamic display model design, added and expanded a factor for sense of presence from the information stance, thus striving to advance it as the principle for the dynamic display for MR space.
- **Evaluation using QFD diagram of dynamic display principles we developed.** It has been put through the process of interface characteristic evaluation which made up the existing MR space by applying the principles developed for the purposes of dynamic display model design to QFD diagram. Via this process, weak points in the existing models were realized and the next step should be applied in order to achieve the applicable principle.

2 Literature Review

2.1 Presence in MR Space

The sense of presence in the virtual reality environment is defined as the level of certainty that one's self is actually in another environment different from that of the actual place of their presence [11], and the existence of medium environment as opposed to the physical environment. [12], In Schubert(2001) research, 8 factors were

presented including Spatial presence(SP) Quallity of immersion(QI) [13]. Heeter(1992) also classified the sense of presence into 3 types; personal, social, and environmental presence [10]. And in case of environmental presence, there is a close relationship with the spatial presence within the MR environment. Looking closely at the comments related to conditions which satisfy spatial presence as an identifiable factor which assign spatial presence within these spatial characteristics, 'quick response regarding user input(Held & Durlach,1992)', 'level of comfort of the equipment and ease of transfer(Barfield & Weghorst, 1993)', 'the number of suggested and intervened level of senses and course (Steuer, 1992; Kim & Biocca, 1997; Lombard & Ditton, 1997)', 'the level of consistency in sensory information provided by the medium(Held & Durlach, 1992)' among others are mentioned.

Each of the factors in spatial presence have suggested requirements for maintaining the same, in particular spatial presence, 'the number of suggested and intervened level of senses and courses' was mentioned numerous times as an important requirement. Via this requirement, as a research which supports spatial presence, from (footnote) studies, multi-functional, multi-sensory system has been set as the goal. In other worlds, it is a method of approach which adds other sensory elements to the absence of physical, visual, sensory elements in MR space. As another requirement for spatial presence, 'the level of uniformity provided by the medium' can be mentioned. In many studies, it is stated that In order to overcome the lack of spatial presence, MR environment must be similar to that of the actual physical environment. Therefore, breaking away from the interface focused on visualization and conducting research related to interface which can provide sense of space consistent to that of the actual environment is also important. Increased effect of spatial presence can be expected only when the diversification of sensory Information and uniformity can be satisfied.

2.2 Information Presentation in MR Space

AR is a particularly useful visualization technique to overlay computer graphics on the real world. AR can combine visualization method to apply to many applications. However, even after having relocated the interface to MR and augmented reality, virtual components from the visualization methodology aspect still remains as a virtual component. A common problem that can occur in this situation with mixed reality visualization is the perception that the virtual component lies above the real component rather than below its surface. This ultimately serves as evidence that it was not able to provide uniform visual information with that of actual space. Information delivery in mixed real space could be considered as the method to strengthen and complement the information visualization to increase the existence felling and the trial to increase the existence felling along with other senses.

Research related to information presentation in MR has been focused mostly on studies related to decreasing occlusion between object and information, applying spatial context on color and transparency, transforming information, real component overlay method, and others which are related to the possibility of including visualized virtual components to the real space without a sense of foreign substance.

The trial to increase the existence felling by providing other senses has been executed through the realization of modalities research in intermodal, TUI, OUI and NUI. However, it is quite often that visual involvement requirements provided by

GUI are lost in the interfaces that try to provide these multi-sensing. For example in the study about Shape Display by Follmer(2013), limitations were raised like speed problem in information and image conversion, readability which is caused by the deceasing resolution [9].

3 Development of Presence Principles for MRs

In this study, principles of dynamic display supporting the presence, which is suitable for construction of MR space, are to be reorganized and to be developed as the quantitative evaluation indicator. For this, research of this chapter is conducted according to the order of Fig. 1.

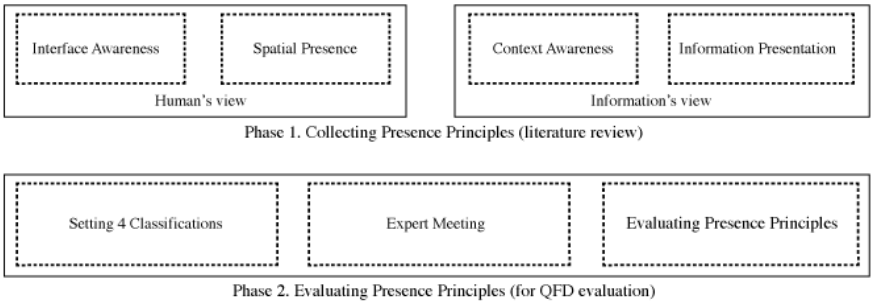


Fig. 1. Research framework

Through this, the evaluation frame focusing more on the interface and space construction elements are to be made ultimately by focusing the wide range presence indicator as the indicator for MR space design, and this frame is to be utilized for the alternative evaluation of next step research.

3.1 Collecting Presence Principles

Before suggesting and reviewing the dynamic display supporting the pesence which is suitable for construction of MR space, the indicator should be prepared which could measure and evaluate the 'Presence which is suitable for construction of MR space'. Therefore, indicators were collected which were officially approved by the existing collected presence principles studies like Table 1 and additionally, indicators about the Presence of the information which is suggested by this display were collected as well as by the people who are experiencing dynamic display.

When the information is suggested in the place which is mixed with real world, the presence about the space is required, which is different from the case when the information exist in complete virtual space. For example, based on the interpretation capability about information space and modality utilization capability in multimodal, it could mean how much this information has the autonomy in mixed reality. Like this, as the Presence indicator was added from the information perspective and duplicated contents in Presence indicator earlier suggested in Table 1 were arranged, the results could be summarized as 20 major categories like Table 2.

Table 1. Collected presence principles[2][4][7][9]

References	Presence Principles
Witmer et al.(1998)	Degree of control, Immediacy of control, Anticipation of events, Mode of control, Physical environment modifiability, Sensory modality, Environmental richness, Multimodal presentation, Consistency of multimodal information, Degree of movement perception, Active search, Isolation, Selective attention, Interface awareness, Scene realism, Consistency of information with the objective world, Meaningfulness of experience, Separation anxiety/disorientation
Schubert et al.(2001)	Spatial presence, Quality of immersion, Involvement, Drama, Interface awareness, Exploration of virtual environment, Predictability & interaction, Realness
	+
Information's Presence Principles	Context accepted state changes, Perception Location, Interaction tools (Kersten-Oertel et al, 2013), Affordance, Constraints (Follmer et al, 2013)

Table 2. Deleted and extended presence principles

Extended Presence Principles of MR space design
Interface awareness, Meaningfulness of experience, Perception Location, Affordance, Scene realism, Separation anxiety/disorientation, Spatial presence, Quality of immersion, Physical environment modifiability, Environmental richness, Consistency of information with the objective world, Information presentation accuracy, Diverse multimodal presentation, Consistency of modalities, Context accepted state changes

3.2 Classifying Presence Principles

In order to classify the determined presence principles and to make importance rating, 4 major categories were classified and meeting was conducted with 14 experts. For the presence of users and information, 4 categories of Interface awareness, Spatial Presence, Spatial Context Awareness, Degree of freedom in decision of Information Presentation method were classified as follows. The definitions of these groups are as follows.

- Factor 1. **Interface awareness:** The interface awareness group consists of principles related to the degree of understanding about the user MR space and level of communication.
- Factor 2. **Spatial Presence:** The spatial presence group consists of principles related to the immersion about the space and sense of existence that is equivalent to real world or better.
- Factor 3. **Spatial Context Awareness for Information Presentation:** The spatial context awareness group consists of principles related to the correspondence of the context information with MR space.
- Factor 4. **Degree of Freedom in Decision of Information Presentation Method:** The degree of freedom in decision of Information Presentation method group consists of principles related to the restriction in suggesting methods and ratios of degree of freedom.

Table 3. Results obtained from a principal component analysis

Principles	Factors			
	1	2	3	4
Interface awareness	**.605**			
Meaningfulness of experience	**.614**			
Perception Location	**.782**			
Affordance	**.824**			
Scene realism		**.712**		
Separation anxiety/disorientation		**.891**		
Spatial presence		**.906**		
Quality of immersion		**.984**		
Physical environment modifiability			**.744**	
Environmental richness			**.612**	
Consistency of information with the objective world			**.673**	
Information presentation accuracy				**.745**
Diverse multimodal presentation				**.885**
Consistency of modalities				**.714**
Context accepted state changes				**.912**

In this study, each factor included principles with factor loading of at least 0.6. The result of this process is shown in Table 3. As a result of the analysis of the main factors, extended presence principles were classified into four different groups (see Table 4).

Table 4. Classified presence principles

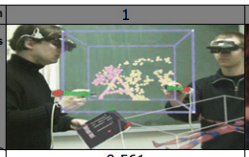
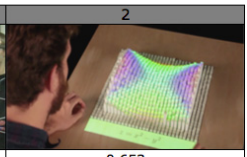
Interface Awareness -Interface awareness -Meaningfulness of experience -Perception Location -Affordance	**Spatial Immersion** -Scene realism -Separation anxiety/disorientation -Spatial presence -Quality of immersion
Information-Interface Communication -Physical environment modifiability -Environmental richness -Consistency of information with the objective world	**Information Presentation Method** -Information presentation accuracy -Diverse multimodal presentation -Consistency of modalities -Context accepted state changes

4 QFD Evaluation Followed Presence Principles for MRs

Quantitative analysis frame was prepared by substituting the expanded presence indicator, which was earlier deducted in QFD diagram. In order to increase the presence here, 1) application that has the method to strengthen the visualized information and 2) application providing diverse sensory information (e.g. Tangible User Interface) was QFD evaluated and analyzed. This has an objective to draw the necessary guidelines in designing the concept model of dynamic display in the future.

Based on the measurement of the degree of relation in each factor, 1 to 10 points were graded according to the importance of QFD diagram weight. After the evaluation of two applications, points were totaled and compared for each category by multiplying the scores and related weights in each principle.

Table 5. QFD Evaluation followed Presence Principles for MRs

Row	Weight / Importance	Demanded Quality (Extended Presence Principles)	Quality Characteristics	Column 1 	Column 2 
1	3.0	Interface Awareness	Interface awareness	0.561	0.653
2	3.0		Meaningfulness of experience	0.753	0.755
3	6.0		Perception Location	0.646	0.423
4	7.0		Affordance	0.417	0.879
5	3.0	Spatial Immersion	Scene realism	0.672	0.761
6	7.0		Separation anxiety/disorientation	0.659	0.756
7	8.0		Spatial presence	0.768	0.863
8	9.0		Quality of immersion	0.621	0.836
9	5.0	Information-Interface Communication	Physical environment modifiability	0.432	0.869
10	3.0		Environmental richness	0.534	0.521
11	4.0		Consistency of information with the objective world	0.722	0.475
12	6.0	Information Presentation Method	Information presentation accuracy	0.892	0.753
13	8.0		Diverse multimodal presentation	0.457	0.685
14	5.0		Consistency of modalities	0.856	0.673
15	9.0		Context accepted state changes	0.512	0.974
Total	88.0	Total Value		52.789	67.591
		Min Relationship Value in Column		Affordance =0.417	Perception location =0.423
		Max Relationship Value in Column		Information presentation accuracy =0.892	Context accepted state changes =0.974

In Application 1, relatively high scores were obtained in the categories of 'perception location', 'Consistency of information with the objective world' and 'Information presentation accuracy'. This gives a conclusion that existence felling is increasing from the direction not to restrict the involvement of users by 'providing correct information' or 'continuity and consistency of information providing methods'. In case of Application 2, positive scores were obtained in active information providing methods by the display, which are 'Affordance', 'Quality of immersion', 'Physical environment modifiability', 'Diverse multimodal presentation' and 'Context accepted state changes'. Reason why the scores in application 2 are high in spite of similar total score when weight values are totaled is that delivery power was increased by actively using the real world objects that were passive and static in information delivery

methods. This proves that the information providing which interprets or utilizes the changing spaces positively in MR environments affects the increase in existence feeling as much as the continuous and consistent information providing does due to the dynamic characteristics of the space.

5 Conclusion

In this study, 15 presence principles were developed for dynamic display design and evaluation of dynamic display in mixed reality space. This is a research to subdivide and classify the indicators collected through the researches about the existing measurement and evaluation of the existence felling and information suggestion methods in mixed reality as the evaluation principles of the displays and multimodal's interfaces that construct the mixed reality. Additionally, by constructing QFD evaluation frame based on this presence principles and evaluating the interface, which composes the mixed reality, research results were tried to be reflected in the future researches. While the measurement of existence felling in the zone was a research that covers the entire range of mixed reality in Significant improvement, it was considered that output modality was rechecked by focusing through the space for information providing and information providing methods and the criteria could be extracted which could be used in dynamic display design.

It could be identified that the existence felling in the interface which supports the change of the space that becomes the interface is relatively high than the standardization and continuity of delivery method through QFD and the existence felling which is utilized in the interface is relatively high than the existence felling which is attached in the interface. However, if this interface is not supported by the correct information delivery, the capability that the existing visualization oriented interface maintains the existence felling is measured to be high. This study has some limitations. First, this evaluation frame should analyze and evaluate the characteristics of more diverse applications, but only two representative applications were evaluated. The procedures to draw the problems through this also remain as future assignments.

Therefore, future work should be expanded and subdivided as the indicators, which evaluate the mixed reality display method, UI composition and information delivery methods etc and subsequently, the criteria should be deducted by analyzing the problems. As the next step, complementing alternatives can be suggested and prototypes can be realized. It is considered that dynamic display optimization model based on mixed reality could be constructed through this and based on that, It could be possible that the development of applications providing the improved existence feeling to the users.

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