Web-based an Emotion-Responsive Color Adaptation Process for Interactive Virtual Building Model

JuYeon Kim, HyunSoo Lee

Yonsei University, Housing & Design Media Lab.
412 Samsung-gwan, 134 Shinchon-dong, Seodaemun-gu Seoul, 120-749, Korea.
Juri88@yonsei.ac.kr

ABSTRACT: The primary objective of this research is to realize an adaptable online architectural virtual reality (VR) model whose color attributes can be changed dynamically according to the identified emotional state of the user. We believe that the current approach to developing electronic based design environments is fundamentally defective with regard to support for multi-person multi-modal design interactions. This paper outlines new facilities within ubiquitous media spaces supporting embodied interaction between human-emotion and computation. Also This paper addresses how to capture a specific user emotion through the web and use it for modifying architectural VR model mainly for its color adaptation. This adaptation process consists of three phases: 1) identification of the user emotional state projected onto the selected paintings 2) translation of the extracted emotional keywords into a pertinent set of colors 3) automated color adaptation process for the given VR model. In this paper, we introduced a method of using well-known paintings and their variations to derive online viewer emotional state which can be utilized to find a new color coordination scheme reflecting the identified emotion. This color harmony scheme can provide a useful information for a dynamic color adaptation for the objects embedded in the given VR model. The outcome of this study could enable an interactive and dynamic architectural VR model supporting emotion-responsive interior design simulations or the realization of an architectural environment where interior colors are changed according to the captured mood of the occupant.

KEYWORDS: Emotion-Response, Virtual Reality Model, Color Adaptation

1. INTRODUCTION

With technological development, space design has become more complex. This complexity has placed greater burdens on the Architect designer and created the need for specialists to support particular aspects of design. “Ergonomics” or “Human factors” is concerned with designing to meet the needs of human users. It draws on disciplines such as psychology and physiology for information and techniques. Part of the emotional ergonomic contribution to design is new research on how particular aspects of the built environment affect people (Bennett, Corwin. 1977).

From the human factors to building space, a smart environment is one that is able to identify people, interpret their actions, and react appropriately. Thus, one of the major building blocks of a smart environment is a person identification system (Alex Pentland and Tanzeem Choudhury. 1999). As Japan Sensibility Marketing Research (Kunio Sato, Tesuya Hirasawa, 1996) suggested, emotional product industry is continuously progressing and draws attentions from various domains. An emotion-responsive interface is becoming indispensable in the cyber space for enhanced immersion and satisfaction.

To recognize human emotional state, the Human-Computer Interaction (HCI) is becoming more and more graphically orientated. The evolution of virtual space or VR has led to an innovative human-computer interaction medium with the potential to present the ‘ideal’ interface between users and computer generated synthetic environment. In this context, the advance of Virtual Reality has influenced diversified industries all over the world. Visual elements are undoubtedly the major media for constructing VR model. VR offers an almost unlimited space and it can represent and provide interactions in real-time (Kalawsky, 1998). The majority of virtual interfaces are designed to represent existing physical spaces or structures. However, VR systems are also very powerful for visualizing and interacting with large or abstract multi-dimensional environments (Kalawsky, 1993).

Various tasks in architectural practice, especially design process, are influenced by the digital revolution through the increased use of computers. Ironically, various objects in cyber world are also becoming ‘architectural’ with the increased popularity of the 3-D simulation environments for intuitively constructing and navigating information space. In response to the growing demand, researchers set out to build interactive virtual space capable of being updated according to the user-specific information. Virtual space, seen not only as a technology but also as a mode of experience, brings 3-D objects which traditionally have been described and represented in an abstract way. The importance of communicating affective information is often ignored in interaction design. One of the most important criteria of an interactive interface is to give the user a chance to have a vivid experience with it. Therefore, it is obvious that the pursuit of emotion-associated VR design as a part of user-oriented interfaces will be getting more attention.

2. WHY ADAPTIVE VR MODEL?

If a computer can recognize human emotional state and react accordingly, we might think it has a certain level of intelligence. But in reality, this still is a part of science fiction. It is clear that not a single human can completely recognize their own deep emotion, actually in many instances, people cannot even recognize their own emotions. Internal feelings could remain private as long as we want them to be that way or if we sufficiently conceal them from being known to others. In this case, the external recognizers can only observe or reason about the feelings of others, which always are subject to some uncertainty. Despite this uncertainty, people want to know about each other's emotion to communicate useful feedback. The partial goal of this research is to give computers cognitive capabilities similar to those that people have so that they can respond to a set of perceptual stimuli.

The process in which the colors of an interior space are dynamically changed according to a characteristic affective response of a user can potentially have at least dual purposes. Firstly, it could be used as a simulation tool for interior color design considering adequate color coordination required for the functions and placeness of a specific architectural space. For instance, an operation room in hospital is normally designed with white or green colors to invoke clean, calm, cold, and intense feelings required for the room functionality. This color coordination process could be simulated on-line with the proposed system in this research. Secondly, emotion-responsive interior space might be possible by utilizing controllable architectural components such as walls, floor, and ceiling the color of which could be changed depending on the occupant's mood or emotional state. If this visionary scenario is implemented, a therapeutic interior color adaptation will be possible lessening, for example, a depressive mood with complementary color scheme suggested by the system in this research.

3. ASSESSMENT METHODS OF EMOTIONAL SIGNALS

According to the researches on human senses, our all five senses can be connected with those various signals such as physiological signal, bio-chemical signal, psychological signal, and behavioral signal. The data on human emotion is derived from these human senses (i.e. visual, auditory, olfactory, tactile, and taste). For instance, the physiological signals for various visual stimuli can be acquired using EEG (ElectroEncephaloGraphy), ECG(ElectroCardioGram), GSR(Galvani Skin Resistance), RSP and PPG(PhotoPlethysmoGram). Both measurement instruments and the systems which can manage, analyze, and evaluate the acquired signals have been developed. There also have been the development of an optimal bio-signal measurement method along with emotional criteria using psychological, linear and nonlinear chaos analysis methods. With the information on these preceding researches, 'up-to-date' emotional data analysis systems could be summarized like the one shown in Figure 1 (Affective Computing Research Group, MIT Media Lab, 2000).

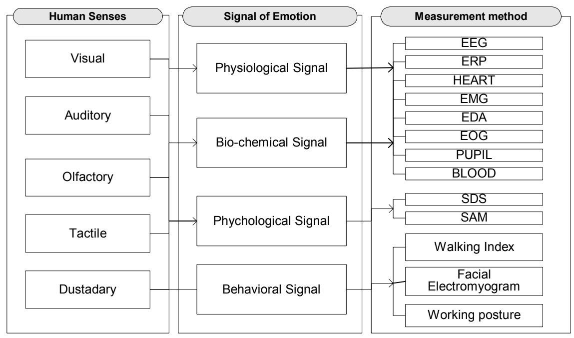


Figure 1. Assessment methods of human emotion

4. STATUS OF EMOTIONAL SYSTEM TECHNOLOGY

An effective human-computer interaction allows emotional information to be communicated by the user in a natural and comfortable fashion. Emotional information also somehow needs to be recognized by the computer to support genuine interactions. At the MIT's Media Lab, researchers are performing studies to give computers a capability of understanding natural modes of human communication. Those researches include the interpretation of signals such as facial expression, vocal intonation, muscular movement, gesture, respiration, and even autonomic nervous system signals. Groups of sensors are designed to track user behaviors that might signal frustration and to relate the user behavior with the current state of the computer. The Media Lab emphasizes that sensors are important part of an 'Affective Computing System' because they provide information about the wearer's physical state or behavior. It is discussed that they collect data in a continuous way without having to interrupt the user. Several projects in sensing which influenced our research are listed below on Table 1 (Affective Computing Research Group, 2000).

In this research, we studied visual stimuli for measuring emotional states based on the protocols for necessary experiments. In Figure 2, we marked bold lines and shadings on the elements we selected as the elements for our proposing emotional measurement system. The graphical structure itself is organized hierarchically based on the AIP cube (Zelter, 1994) to represent various technologies involved in VR.
Our target VR system, mainly for demonstration purpose, is using a 'monitor' for visual display device in 'presence' category, 'attribute and task modeling' as a kind of object modeling in 'autonomy' category; a 'mouse' as gesture device, and 'selection image' as a method in 'interaction' category (Figure 2).

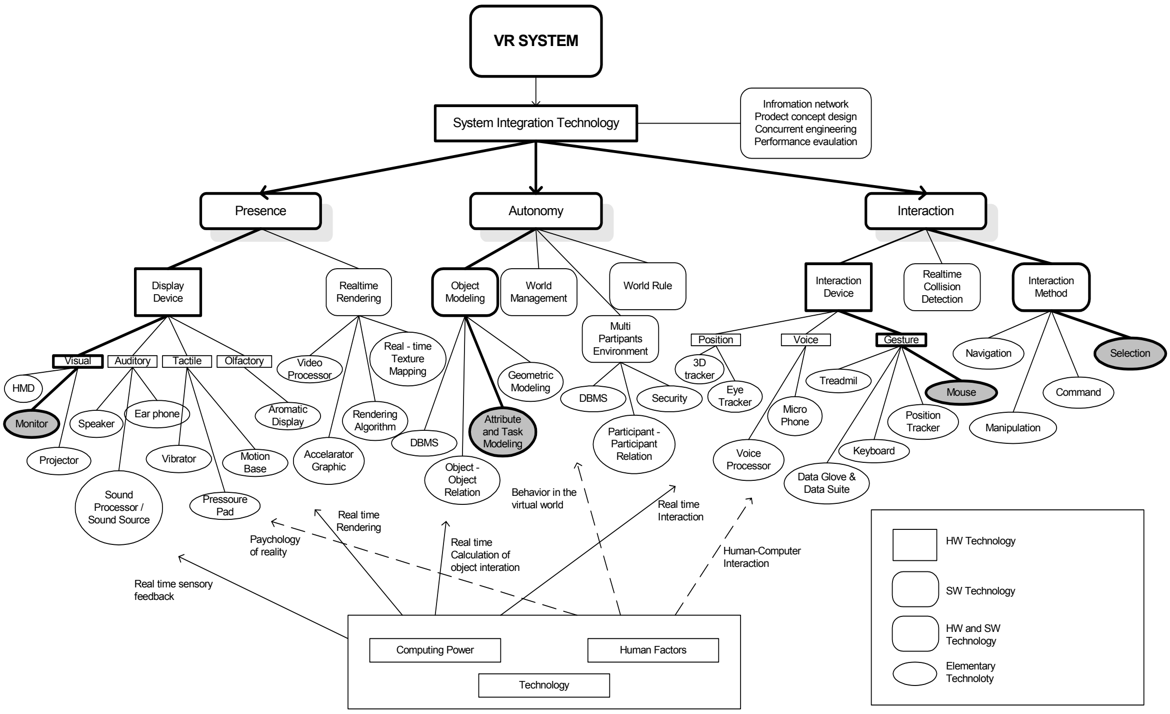


Figure 2. Illustrative genealogical framework of VR technologies (Lee, 1997)

Table 1. Types of emotional system technologies (Affective Computing Research Group, MIT Media Lab, 2000)

Type	DESCRIPTION
Affective Carpet	This deformable surface made of conductive cloth and conductive foam detects continuous pressure with excellent sensibility and resolution, and re-expresses the applied pressure musically.
Affective Jewelry and Accessories	Wearable jewelry and other clothing designs with embedded sensors for sensing physiological changes associated with emotions
Expression Glasses	A wearable device which allows any viewer to visualize the confusion and interest levels of the wearer.
Frustration Experiment Design	A psychological experiment designed to elicit a “frustration response”, and to synchronize computer events with multiple channels of physiological data used to collect data for the frustration detection study.
Smart Shell	When a person is going to be at a “burned out” performance level, this system can it help motivate the person.

5. SCOPE OF THE SYSTEM DEVELOPMENT

The components and processes for the emotion-responsive VR systems developed in this research are as follow.

Construction of visual stimuli database containing various pieces of visual art and images derived from well-known paintings providing necessary stimuli for emotional measurement based on the experiment protocols.

Extraction of emotional key word and the identification of color coordinate key words based on the tone and brightness of the selected painting by the
user.

Establishment for an emotional color palette that determines a set of colors for VR adaptation. This process is done by using Expert Color Coordinate System based on a series of built-in heuristic rules to coordinate the colors of the participating objects in the target VR space which are floor, wall, ceiling, and furniture.

Construction of an adapted VR model by changing colors of those objects selected in the virtual interior system modeled by 3D Max and EON Reality Studio using an adaptive user interface provided on the web.

6. COLOR PALETTE - KEYWORD IMAGE SCHEMA

When people see a certain combination of colors embedded in an image, a common feeling could run through their minds. Based on the research that maps adjectives with these images and colors, a scale has been developed such as the Key Word Image Scale. With this scale, three axes have been introduced for obtaining an objective evaluation uninfluenced by value judgments based on personal preference, or by the context of assessment. The words and colors located at the same point along the warm-cool and soft-hard axes have the same images; it is the image that constitutes the connections between the word and the color. Theses image words are not only applied to colors but also can be applied to shapes, patterns, materials, interior design, fashion, and product design by providing a way of organizing images in a psychological view point. (Kobayashi, 1990)

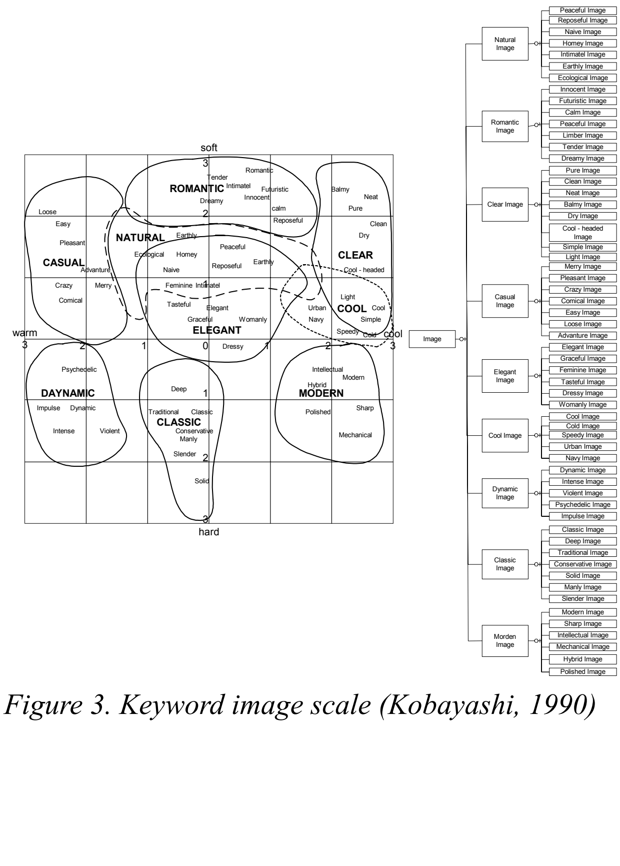


Figure 3. Keyword image scale (Kobayashi, 1990)

7. EXPERT COLOR COORDINATION SYSTEM (ECCS)

We propose ECCS an Expert Color Coordinate System in the VR space based on Kobayashi color image scale. In this research, it's focus is a limited set of objects in the target VR model such as floor, wall, ceiling, and furniture. A suggested emotional color palette extracted through the visual image stimuli is needs to be coordinated for each of those architectural components to change the color attributes of the given VR model. ECCS is automatically coordinating colors for each of the objects in VR space based on the inference system built upon expert interior designer's knowledge and experience.

ECCS is a rule-based color coordination system allowing knowledge to be represented as a set of heuristic rules which can specify a set of actions to be performed for a given situation. There are some exemplary heuristic rules for the research. For instance, how to coordinate the color of each object in the VR house interior model could be ordered by brightness of the colors. Usually, dark color is applied to floor and light color goes to ceiling. Unlike the first stage of the research where the emotion system has an emotional keyword from color scale, ECCS supports mainly the second stage of extracting color coordinate key words to establish the final color palette.

Before using ECCS, the user needs to decide whether or not this automated decision support tool should be used. When user does not want to use the system, he/she can either manually allocate colors to the objects or just leave the task to the random color coordination algorithm. In case the user manually changes the color of each object, the color harmony is out of his/her own color preference. When ECCS is selected, a specially arranged color harmony is expected to emerge out of the given emotional color palette.

Figure 4 illustrates the mapping between the selected emotional key words & color coordinated key words (i.e. natural, romantic, clear) and the corresponding color palettes. Each color in the palette is represented in CMYK values. Between the second set of images and the color coordinated palette, four different types of lines are marked to differentiate four adaptive objects in the target VR model. Each of them is also connected to a certain color in the palette.

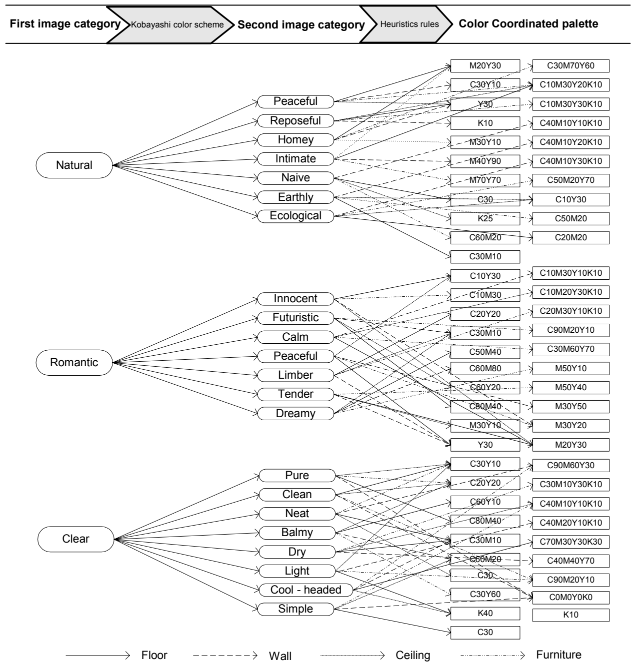


Figure 4. Example of an expert color coordination chart

8. PROPOSED EMOTION INFERENCE PROCESS

A user selects favorite image from the first set of images prepared from well-known paintings which have distinctive emotional implications. The user would interact with the system through a mouse event to select an image. Each of those posted images will have emotional keyword possibly backed by an on-line survey on the relationships between visual cognition and affection.

Figure 5 shows the images chosen for the first set of visual stimuli to extract emotional keyword. It shows different paintings tagged with emotional keyword such as natural, romantic, clear, casual, elegant, cool, dynamic, classic, and modern. It also shows the color coordinate keywords elaborating the subtleness of the proposed emotion inference process.

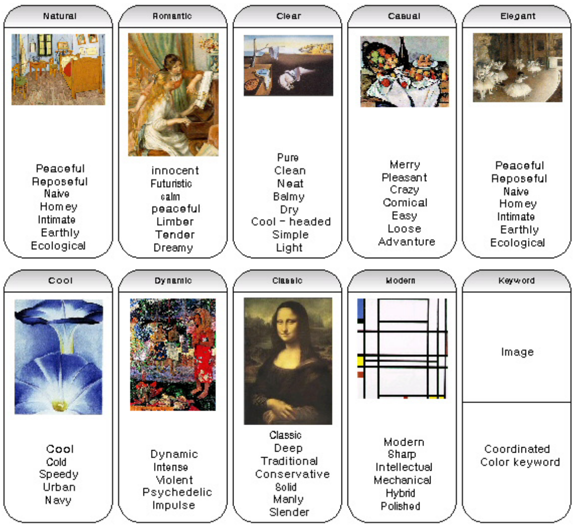


Figure 5. First set of image stimuli for emotion inference

9. CONTROLLED VISUAL EXPERIMENT

This step continuously performs a controlled experiment based on the user's first image selection. From the selected original painting, the user is supposed to choose one image among many different tone – varied images.

Table 2. Second set of image stimuli for the controlled visual experiment

No	Image	Tone /Color Balance			Brightness	Emotional Keyword
Image0		Shadow – Color levels			Levels +10	Natural
		Midtones – Color levels				
		Highlights – Color levels				
Image1		-12	0	-63	+10	Peaceful
		0	0	-100	+0	
		0	0	-19	+0	
Image2		-13	-23	-70	+10	Reposeful
		100	+15	-77	+0	
		+53	0	-28	+0	
Image3		+69	0	-50	+10	Homey
		+21	-9	-14	+0	
		+33	0	+3	+0	
Image4		+48	-69	+47	+10	Intimate
		+23	-97	+48	+0	
		+27	-31	+21	+0	
Image5		-32	-10	+70	+10	Naive
		-54	-18	+83	+0	
		-20	0	+52	+0	
Image6		-38	+24	+36	+10	Earthly
		-44	-27	+69	+0	
		-54	0	-51	+0	
Image7		+31	+57	-78	+10	Ecology
		-58	+100	-14	+0	
		0	+17	-27	+0	

These second set of images are prepared by a systematic color tone variations of the chosen painting necessary for deriving a coordinate color combination. The color tone variation process is based on different balance levels described on the twelve-part color circle; ranging from the primary colors (yellow, red, and blue) to the secondary ones (orange, green, and violet). A tone has three ingredients such as shadow, mid-tone and highlight. Each of the ingredients has the color levels which are consist of cyan-red, magenta-green, and yellow-blue.

10. EXEMPLARY DEMONSTRATION OF THE SYSTEM IMPLEMENTATION

1. Implementation process

Figure 6 demonstrates an overall process of the proposed emotion-responsive Virtual Reality model focused on color adaptations. This process starts from the log-in point and ends its cycle when the user experiences or sees the adapted virtual reality model. In between, there are multiple steps to be followed such as the interpretation of the emotion- associated painting chosen by the user, the identification of the user's emotion through the extracted color coordinate keywords using tone-varied multiple images for the chosen painting based on Kobayashi image keyword scale, a random or ECCS supported color coordination with the derived color coordinate palette, and finally, an automated color adaptation visualization process for the target objects in the original virtual model.

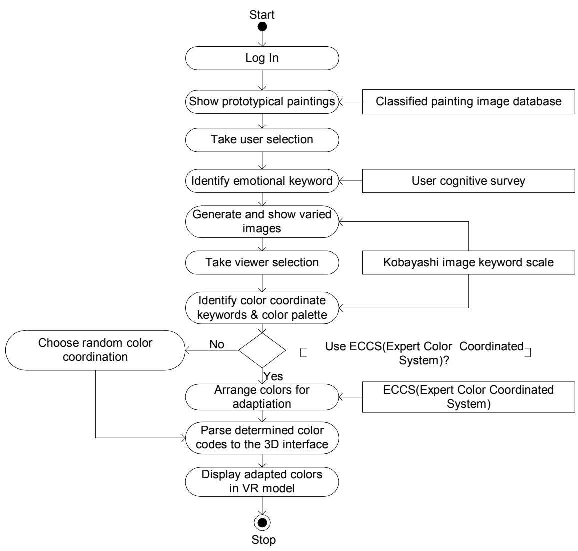


Figure 6. Activity diagram showing the proposed system's internal process

2. 3D MAX – 3D SPACE MODELING

To build an initial 3-D construct as the basis for the virtual reality model on the web, we used 3D MAX software. Figure 7 shows a snapshot of creating 3D objects in the interior space of an imaginary house. Those objects are internally organized in a hierarchy for further modification or changes of colors. (Figure 8)

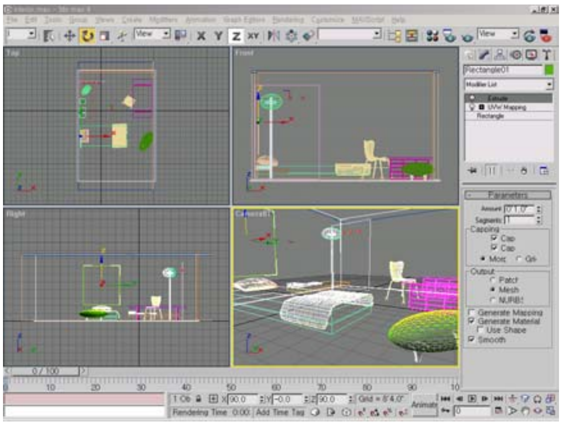


Figure 7. 3D modeling of interior objects

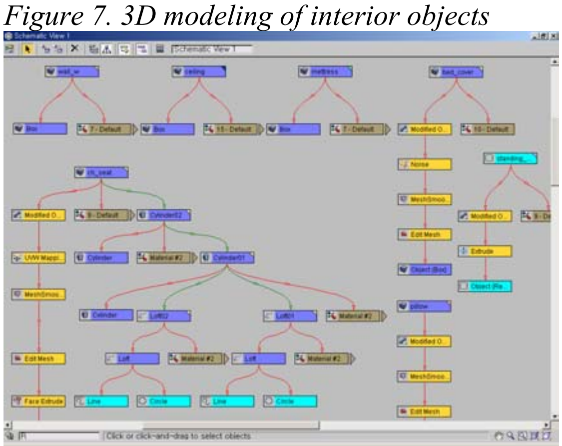


Figure 8. Hierarchical modeling tree of the created objects

3. EON Reality Studio – Adaptive simulation

As for the VR implementation environment, we chose EON Reality Studio for maximum performance and easy integration with the web environment. Figure 9 and Figure10 show the exemplary processes where the created 3D objects are imported and further processed to become VR enabled EON objects the attributes of which are eventually manipulative on the web. Figure 11 and Figure 12 demonstrate object color specification and the final VR simulation process.

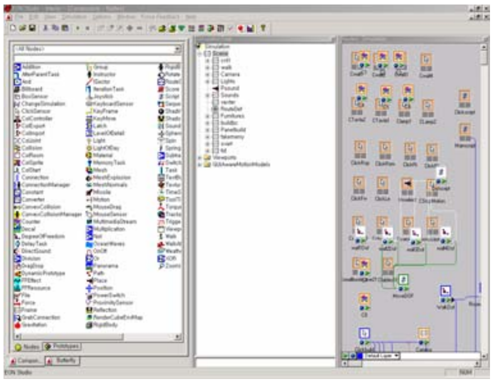


Figure 9. EON reality studio window

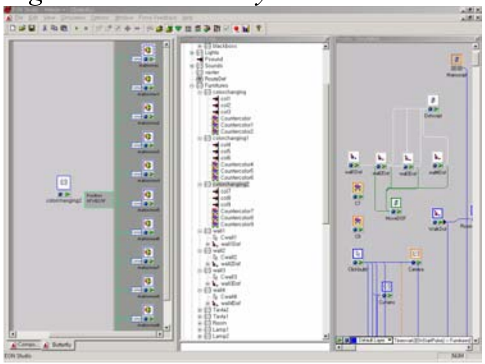


Figure 10. Color node tree in EON

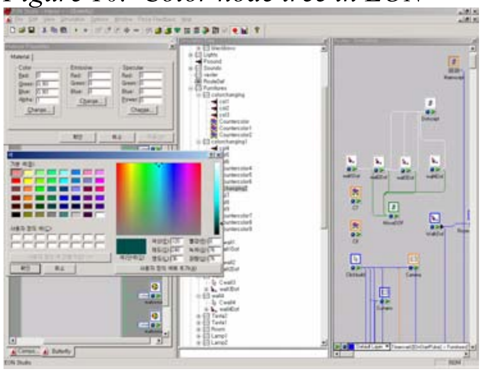


Figure 11. Color control window in EON

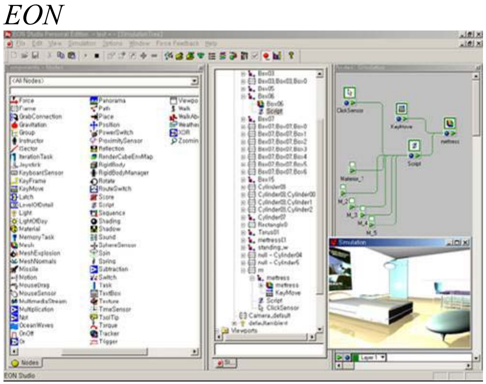


Figure 12. Simulation window in EON

HTML documents are designed to display the first and the second sets of image stimuli and to obtain a user's response to them. To modify the color attributes of the chosen 3-D objects such as floor, wall, ceiling, and furniture, we generated Event nodes (shown on the left in Figure 13) which are embedded in a HTML document and associated with event Scripts and Objects. From this nodal representation of a virtual model provided by the Eon Reality Studio, a mouse click action on any of the ‘Event’ nodes (N01 –N07) can trigger the execution of the corresponding event Script to redefine color attribute for each of the 3-D objects represented as a material.

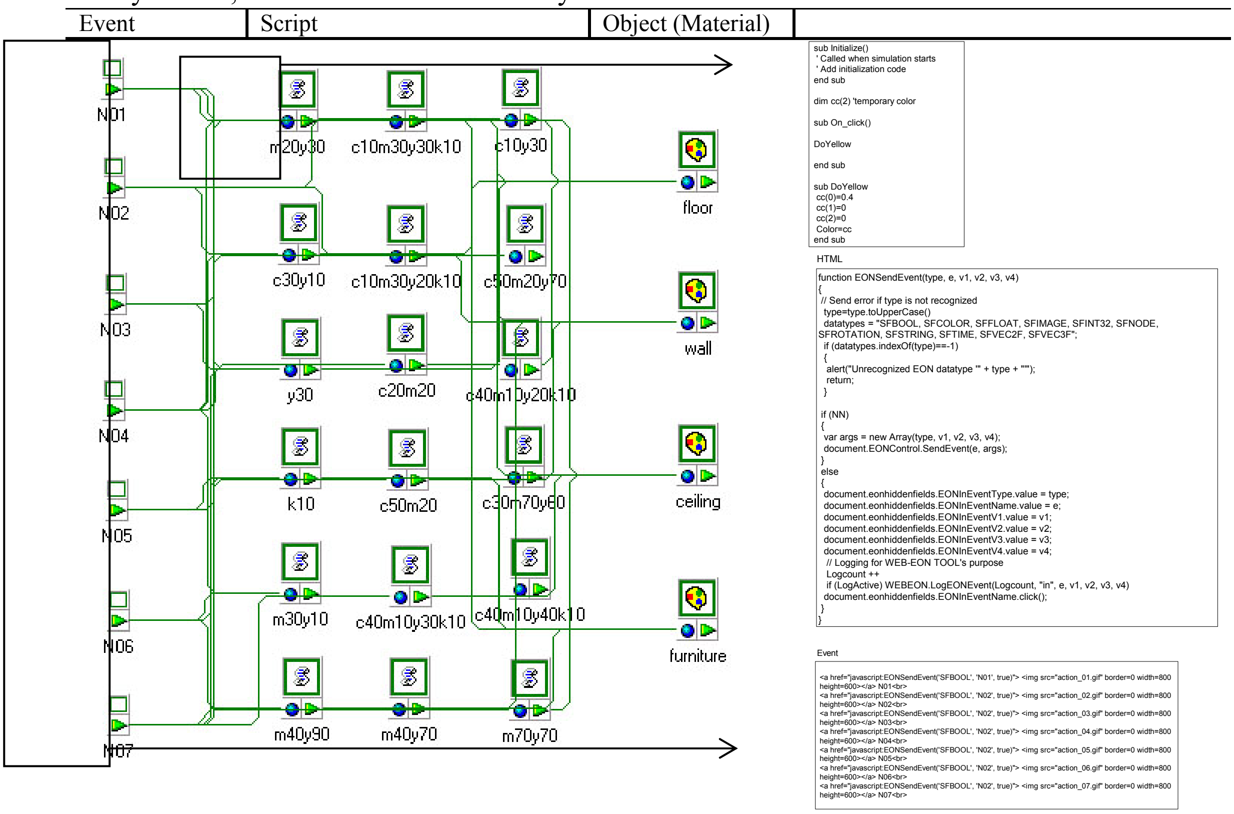
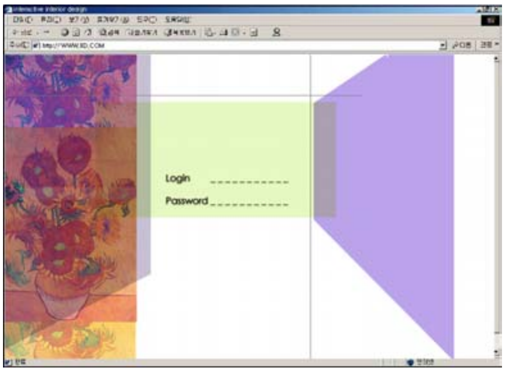


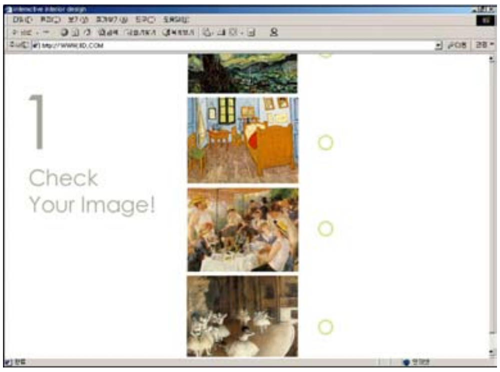
Figure 13. Node Tree describing the color modification process of the EON objects and corresponding source codes for the selected nodes

11. ADAPTIVE VR INTERFACE

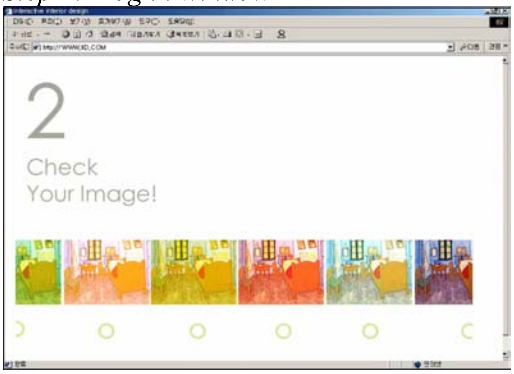
As a demonstrative system implementation, we constructed a web-based emotion-responsive VR interface. In the beginning, user passes a log-on process by typing in his/her ID and password (Step 1). Secondly, the first set of visual stimuli shows up for the user to select an image out of them (Step 2). From the chosen image, a series of tone-differentiated images are displayed in the second visual stimuli interface for user’s selection (Step 3). The emotional keywords extraction and color coordination for VR simulation are processed internally. Eventually, the user is able to see the effect of his/her actions by experiencing an emotion-adapted virtual reality model in real-time (Step 4).



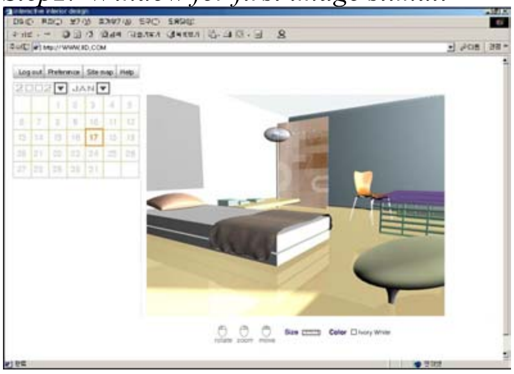
Step 1. Log in window



Step2. Window for first image stimuli



Step 3. Window for controlled visual experiment



Step4. Color – adapted VR model

12. CONCLUSIONS

This study has suggested that emotional intelligence, being based on the emotional keyword-driven color schema necessary for magnifying the role of emotion in human intelligence, can be a subset of machine intelligence and that the way for man-machine interaction resembles the mode of inter-human interactions.

As an attempt to make an interactive and adaptive virtual space, this research tried to construct a methodological frame work to develop a user-centered VR system allowing interactions between the user and a virtual space beyond the conventional limitation of just imitating real world or using a straightforward web interface. The primary requirement this study tried to fulfill was to maximize the sense of emersion and satisfaction for using VR objects on the web, which has been partially explored through a color-adaptive VR model based on the identified user's emotional state.

The advantages of the proposed emotion-responsive and color-adaptive virtual reality model are connected with its capabilities to invoke users' active involvement and to explore a potentially new way of interior design in the future. The research has been theoretically based on the principles of emotion and colors as well as the emerging discussions on the emotion-responsive virtual space. The research process itself has been directly formulated through understanding the relationships between these theoretical bases. Eventhough the proposed set of keywords representing emotion-color relationships identifiable through a cognitive survey might not best reflect potential users' emotional state, it could be, at least, a starting point to develop a human-centered virtual reality system supporting dynamic interactions between users and virtual spaces in the future.

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