Mixed Reality System for Virtual Interior Design

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Abstract

In this paper, a mixed reality system for virtual interior design is proposed. The mixed reality technology is a concept covering augmented reality that shows graphic objects integrated to a real environment. This paper describes design of a virtual interior design system that can change and display building inside interior design using mixed reality technologies in a ubiquitous computing environment. The virtual interior design system proposed in this study consists of a hardware platform that can receive and process data from various sensors and a virtual interior design application that displays interior design based on the processed information. The system proposed in this paper will develop into services to the extent which can be directly used in the field if subsequent studies are carried out

Keywords: *Mixed Reality, Virtual System, Interior Design, Ubiquitous Computing Environment*

1. Introduction

With the development of computer hardware and network technologies, mobile information devices such as cell phones and tablets Mobile information devices are developing. In particular, the advent of Apple's iPhone is called a new revolution in information electronic field, opening a smart terminal era. The smart terminal with convenient mobility blends mobile communication functions and computing functions and interface in a user-oriented design made it possible the birth of new functions. Accordingly, a lot of developers work on related application development, and the government ministry spares no efforts. Even several years ago, mobile devices stopped at taking charge of secondary and scrappy functions such as mobile communication and tag reader in biological or industrial sites; however, with the emergence of smart phones, various applications can be provided anytime and anywhere using a great quantity of information processing power as well as information communication. This informs us of the upcoming ubiquitous [1] era.

Ubiquitous computing is a concept proposed first by Mark Weiser at Xerox Palo Alto Research Center in 1988, referring to an environment in which users can have services of seamless computing anytime and anywhere. For this, all objects should be connected to a network, and an interface with which anyone can easily use devices without any difficulties should be provided. In addition, anytime and anywhere in the real world, computing should be available, and services can be changed depending on the users' circumstances [2].

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Thanks to this ubiquitous computing environment, sensor network infrastructures in which various sensors spread on objects and these sensors are connected to the network have been constructed, so necessary information can be obtained in real time. In addition, as various sensors such as motion sensing sensors, position sensors and visual sensors, etc. are built in the terminal, a new type of services become possible. For example, through a motion sensor built in smart phones, how many times a user tossed and turned sleeping in bed became known, and through a position sensor, where a user is at can be grasped in real time.

Also, with the sensor technologies and communication technology, as the accuracy of information recognition gradually gets higher, the method of showing the information attracts more attention. In this environment, as a method of displaying information, augmented reality (AR) technology is much in use. Augmented reality is a technology that shows virtual objects in the real world with a user viewpoint [3]. In contrast, the technology that projects the contents of the real world to a virtual environment is called augmented virtuality (AV). These terms on the spectra of virtuality and reality have been arranged by Paul Milgram and Fumio Kishino, who proposed mixed reality (MR) as a concept that covers both augmented reality and augmented virtuality [4]. In a spectrum in which the actual environment and the virtual environment are positioned at both extremities, optionally adding virtual factors to the actual environment is the augmented reality while adding the real elements to the virtual environment is the augmented virtuality. The integration of these two concepts is defined as mixed reality. Figure 1 shows the mixed reality spectrum.

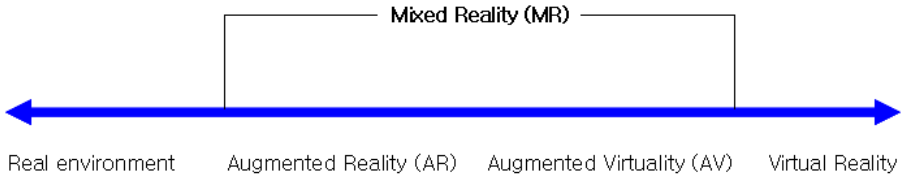

Figure 1. Mixed Reality Spectrum

Mixed reality has been developed around the U.S. and Japan since the late 1990s, and previously it has been used for medical care, broadcasting, manufacturing and military, etc.; however, recently various systems are developed in the fields such as mobile solutions, game, entertainment and education sector, etc. In addition, mixed reality technologies are often used as means of displaying information in ubiquitous computing, so they are developed in the form of u-AR or u-MR.

This paper describes a virtual interior design system in which users can change and view building inside interior design using mixed reality technologies in ubiquitous computing environment.

2. System Overview

In augmented reality or mixed reality technologies, to show overlapping virtual data generated from computer on the images of the actual environment coming in from camera, a process of registration is necessary, in which, existing systems used specific markers attached here and there. And yet, if the above markers are used in a system that displays building inside interior design using mixed reality, much part of the wall or floor are covered, and there are problems in overlapping additional information in the parts where the makers do not look in the screen. In addition, it is possible to show virtual objects in the position of the makers, but it is difficult to show them between the makers and even if so, a lot of makers are necessary and unnecessary makers show on the screen. To solve these problems, GPS Global

Positioning System is used sometimes instead of markers [5]. However, GPS was manufactured for outdoors, it is inappropriate to use it in an interior environment.

This paper measures the distance to the terminal using terrestrial magnetism sensors and supersonic sensors, based on which it describes the method of registering actual environment and virtual objects. And to change interior design in the actual environment, it describes interior design applications that can change wallpaper materials, lighting and visual points, *etc.* The existing virtual interior design systems have not been used in interior design with important sense of realism as they used three-dimensional graphic spaces only, so did not reduce the gap with the reality. Also, in apartment model houses or exhibition spaces for remodeling, by providing only one kind of interior design in one place, various interior designs have not been provided in interior design services. The virtual interior design system described in this paper supplements these weaknesses using mixed reality.

The virtual interior design system in this study is to allow users to simulate drawing interior designs and changing various environmental factors immediately at the sites with one smart terminal without needing another device. Interior design businesses can provide clients limitless interior design factors such as wallpaper, tile, windows and furniture, etc. and the clients of interior design can simulate various interior designs in advance, so their satisfaction can be promoted after the completion.

The mixed reality based virtual interior design system is broadly divided into hardware parts and application parts. Hardware takes charge in collecting, processing and transmitting information necessary in mixed reality while application takes charge of interior design system to which mixed reality can be applied based on the information. Figure 2 shows the structure of virtual interior design system based on mixed reality technology.

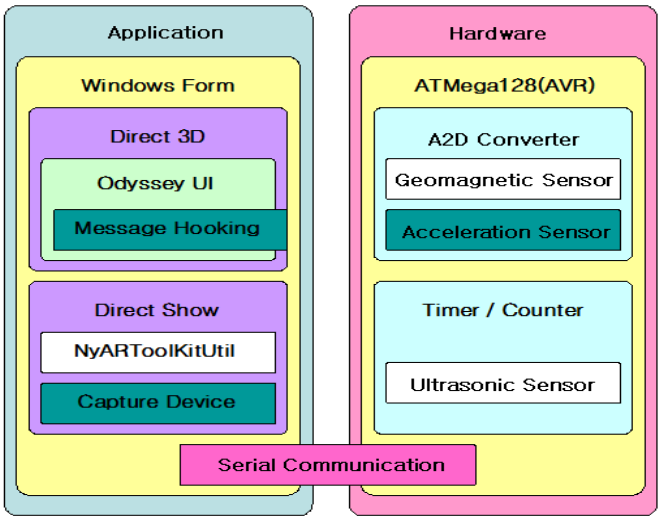

Figure 2. Structure of Virtual Interior Design System

3. Hardware of Virtual Interior Design System

The hardware system grasps the position, direction and acceleration of a smart terminal provided with services. Recent smart terminals are equipped with a terrestrial magnetism sensor that finds directions and an acceleration sensor that finds the position and acceleration of the terminals. So, through these sensors, accurate information from the camera built in the smart terminal is obtained and positioned to the same space as the objects in the three-dimensional virtual space to match the three-dimensional virtual space with the actual space.

To realize the best sense of reality and service various interior designs, it is essential to obtain the accurate position information of the camera.

However, since general phones do not have a built-in sensor that can measure distances, this paper designs and uses an embedded system. An embedded system is one with a built-in computing processing unit to control or monitor a product, hidden in almost all electronic devices such as TV, VCR, DVD player, remote control, washing machine, air conditioning, microwave ovens, video game consoles, toys and mobile phones, *etc.*

In designing the embedded system, among AVR family of ATMEL Company, AVR ATmeda128 [6] that is often used for practices in the field with the highest performance was used. Along with this micro controller, supersonic sensors, acceleration sensors and terrestrial magnetism sensors are used and through an analog digital converter (ADC), data were obtained.

3.1. Sensors

An acceleration sensor senses the dynamic power of acceleration, vibration and shock, etc. and uses fictitious force, electric variation and application principles of gyro. Since acceleration sensors can sense the status of movements of objects in the order of time, it is an essential sensor for measurements of various transportations such as cars, trains, ships and planes, and factory automation and the control systems of robots etc., and its application areas are very broad. It can be broadly classified by detection method into locking retractor type, gyro type and silicon semiconductor type. In industrial instrumentation field, it is used for devices' vibration measurement or structures' vibration measurement, and also for aircraft inertial aviation devices.

In consideration of a bar oscillating body with one fixed side, the topology of the displacement, speed and acceleration of the end precedes 90 and 180 degrees to displacement, and since the output level across a wide frequency band in an acceleration sensor is constant, at the same output, the higher the frequency is, the smaller the displacement gets. In other words, even if the human body feels the same amplitude, man can get a great shock as the shorter the cycle is, the greater the acceleration gets.

Acceleration sensor is usually called G sensor since it uses gravity, and it finds the current slope by synthesizing vertical or horizontal vector in the sensor with gravity vector. By slope, it outputs variable voltages, and the output is received by AVR's analog digital converter, converted to digital value to be used as acceleration value.

A terrestrial magnetism sensor is one that can detect bearing by grasping the flow of magnetic field occurring on the earth. It is also called electronic compass, mostly built in the latest smart terminals. When the magnetic field is vertically caught to an electric conductor in which current flows, the voltage applied vertically in the directions of the current and magnetic field is called hall voltage, and this effect is called Hall Effect. Terrestrial magnetism sensors measure directions using this Hall Effect.

The principle of using a supersonic sensor is to find time between the transmission and reception of supersonic and then to find distances through the velocity of sound wave, 340m/s. Thus, in measuring distances using supersonic, the accuracy of the measurement of time is the key, which AVR's timer function is in charge of. For AVR's timer, the limit of resolution is determined by the maximum number of vibrations used, and this paper used a clock of 16 MHz. In other words, the timer can measure up to 0.00000625 sec., which can divide the time, approximately 0.0000294 sec. when supersonic moves 1cm up to 5 times. Thus, if there are no other constraints, it will have an error rate of 0.2cm to the max. However, supersonic sensors have an error about 3~4cm affected by various environmental constraints such as sound, temperature and humidity around.

Supersonic sensor has the second highest reliability to laser. Since laser is very expensive and has a large physical size, there are constraints, so supersonic sensor is suitable for an embedded system. This paper used a sensor of Hagisonic Co., Ltd.

A supersonic sensor includes a transmission unit that generates sound wave and a receiving unit that senses the sound wave, and it sends out signals to the supersonic transmission unit when the user wants to measure distances. At this time, AVR controls this process, and the AVR sends out waveform signals of PWM (Pulse Width Modulation) randomly made by the user. The supersonic transmission unit sensing this steel plate generates sound wave at the front immediately, and at the same time, the AVR measures time through its timer function. If the generated sound wave reaches the supersonic receiving unit, the supersonic receiving unit sends signals to the AVR's external interrupt, and the AVR receiving the interrupt event stops time measurements. At this time, the value the timer has is the time, and through this information, the distance between the supersonic sensor's transmission unit and receiving unit is calculated. At this time the time when PWM is sent from the AVR to the transmission unit and that when the receiving unit notifies to the AVR through interrupt are extremely short, so ignored.

3.2. Communication

The methods of communication between micro controllers, or between the mixed reality based virtual interior design system and the micro controller broadly include parallel communication and series communication. Parallel communication is made in a place where high speed data transmission is necessary, and since it is made simultaneously at the same clock frequency, on several lines, it has much faster transmission speed than series communication. However, since series communication consists of a single line, its data transmission and reception are slow, but it has merits that it has less number of lines and can communicate to a farther distance.

This paper uses series communication as transmission method, and series communication is divided broadly into synchronous scheme and asynchronous scheme. The synchronous scheme includes the base clock of synchronous clock line and a line necessary for data transmission and reception. In other words, it is a method of transmitting/receiving data sequentially synchronizing with the synchronous clock. This requires high transmitting efficiency and is advantageous for a noisy line or a long distance transmission, used for high-speed transmission of massive data.

Since an asynchronous scheme is not synchronized, it is a method of transmitting and receiving data without a synchronous clock. If there is no synchronous clock, synchronization should be made, which is done by data transmission speed. Often it is called Baud rate, determined by the number of data per sec. Then, the transmitter/receiver on both sides can transmit and receive data at the promised speed. This device is called UART. This asynchronous mode needs bit control Start Bit and Stop Bit notifying the beginning and end before sending data.

4. Virtual Interior Design Application System

If the actual camera's three-dimensional position coordinate and slope, direction and screen information are found through the hardware system, an application that can display building inside interior design using this information is necessary. Since in this paper, the virtual interior design application uses sensor data in the ubiquitous computing environment in which these functions are carried out, this is called u-interior design application.

The screen of a u-interior design application consists of 6 parts: The first one is menu, which includes functions of saving and retrieving mixed reality space status information, selecting the furniture to arrange, changing screen mode and modifying sensor. The second one is a part of setting the degree of the mixed reality, which controls the mixed extent of the screen of the actual camera screen and the virtual space. The third is a part of setting lighting of the virtual environment, which can control the intensity and colors of lighting. The fourth is an object setting context menu in which the materials and patterns of walls, floors and ceilings can be selected. The fifth is a part of displaying the file name of the scene saved currently, and the last one is the screen display part in which the objects of the virtual space and the real images are expressed. Figure 3 shows the screen formation of the developed application.

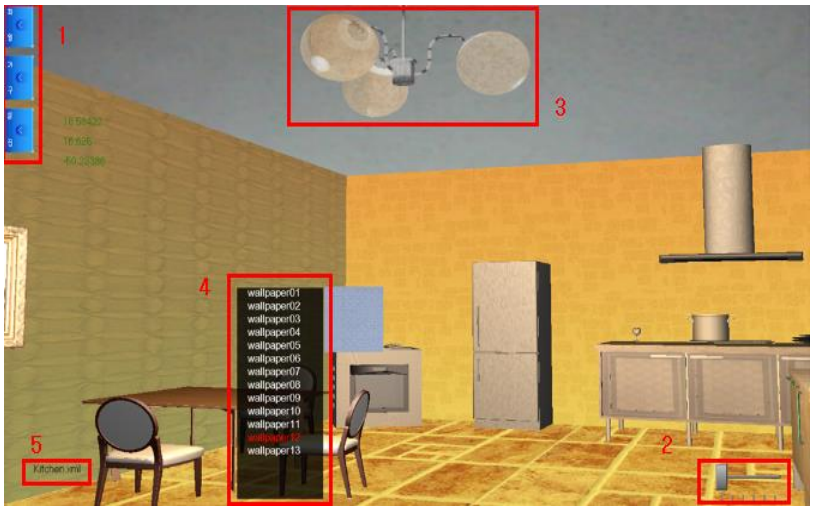

Figure 3. The Screen Formation of the Developed Application

If the category of supplies and furniture to create is selected by selecting furniture in the menu, the list of the categories selected appears at the right top. Mouse over this list provides the thumbnail of each object. Also, the created furniture can be moved and the size can be adjusted and the direction can be modified. Since the arrangement of all objects in the virtual space should be considered, they are not overlapped. Right click on the wall, floor and ceiling to provide context menus of each interior design source, and mouse over each interior design source to show the source's thumbnail instantly.

Place the mouse on the lighting fixture marked on the screen and click the right button to generate a menu tab with which lighting can be controlled. In this menu, controls of the intensity, types and colors of lighting are provided. The types of lighting include direct light, point light and spot light. Click the left button of the mouse to move a lighting fixture to an optional position, and accordingly, it is reflected on the screen in real time. Since lighting may affect colors of actual space as well as virtual space, modification requires the best of care.

The prepared space status information is expressed in structures with information about each object and saved in XML file format. Three-dimensional mixed reality space can be

retrieved from the file in which interior designs are preset and saved. In the retrieved space, users can perform space changes: e.g. add or remove three-dimensional objects.

When a space is retrieved, referring to the XML, the .x files with information about the three-dimensional object are collected and retrieved. At this time, using the retrieved three-dimensional object's transformation matrix information, the space is implemented again. Using this function, the files of the virtual space can be created and provided users who use the services.

4. Outcomes of System Implementation

This paper developed an embedded system as a test bed replacing the smart terminal for the mixed reality based virtual interior design system. The developed system estimates positions by measuring distances in the space through a supersonic sensor, uses a terrestrial magnetism sensor and an acceleration sensor to correct directions and positions. The developed embedded system is shown in Figure 4.

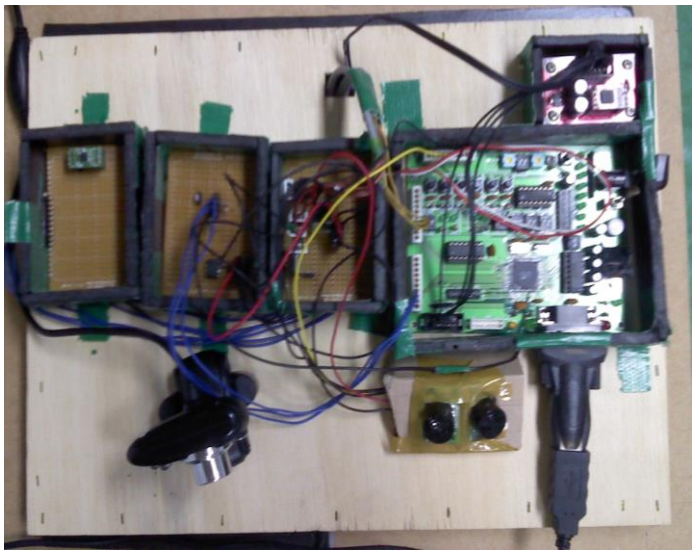

Figure 4. Embedded System Extracting Environmental Information

Position recognition error was about 2~3cm, which is a small one in consideration of the environmental factors such as humidity, temperature and dust in the space.

To perform a virtual interior design using the mixed reality technology, an actual space screen and virtual space are necessary to apply information of the actual camera such as three-dimensional position coordinates, slopes and directions found through an embedded system. The real image of the space used in the test is like Figure 5. If virtual space and real image are ready, the position and direction of the visual point of the camera that shot the real image are found through the hardware system and using this information, the visual point matches. Figure 6 shows the interior design space applying the mixed reality technology. The actual space of the ceiling part and wall part were covered with wallpaper, and the actual space is shown at the bottom part.

Figure 5. Image of Space Actually Used in the Test

Figure 6. Interior Design Space Applying Mixed Reality Technology

5. Conclusion

With the development of mixed reality technologies, new services emerge in ubiquitous environments. This study implemented a system that can display and check interior designs in the ubiquitous environment using the mixed reality technology. In the mixed reality, the problem of registering actual space and virtual space is very important, and this paper used supersonic sensors, terrestrial magnetism sensors and acceleration sensors instead of makers to improve weaknesses of using them. The basic properties of the mixed reality are location-based services and require accurate information; however, position recognition technology is not yet perfect, so there are a lot of difficulties in application development. However, it won't take a long time to implement the future technology like films. The proposed mixed reality based interior design system in this study will develop services that can be directly used in the field if subsequent studies are carried out further, and it is expected that its blending with sensor technology will have a great potential of development.

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