TRANSACTIONS ON ELECTROMAGNETIC SPECTRUM

A Real-time Visualization of Electromagnetic Field Distribution with Markerless Augmented Reality

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Abstract: This paper introduces a method for visualizing electromagnetic field distribution using marker-less AR (augmented reality). Visualization of the electromagnetic field is important for understanding its spatial distribution because the field is invisible. In our previous studies, to display the electromagnetic field distribution in three dimensions, multiple 2D distributions were aligned side by side or displaying contour lines were used. In recent years, an AR technology has rapidly spread, and methods for displaying the distribution of electromagnetic fields on a circuit board and around a fluorescent light in three dimensions have been reported. AR technology usually requires an AR marker which has geometric pattern on it. However, by using the feature points in a monitoring area as a marker, it is possible to display AR objects without special markers. In this study, we introduce a visualizing method which uses the magnetic field meter as an AR marker and visualize a field distribution on a multiple terminal simultaneously. This measurement method is effective not only for exposure assessment purposes, but also as a material for learning electromagnetic field distribution.

Keywords: EMF distribution, Markerless AR, Depth camera, ICNIRP guideline.

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1. INTRODUCTION

Visualization of electromagnetic fields is very important for electromagnetic compatibility testing, design, and exposure assessment. In order to evaluate the presence or absence of biological effects, it is necessary to meet the exposure guidelines established by ICNIRP [1,2] and IEEE [3]. Some Instruments are commercially available that can perform conformity tests based on these exposure guidelines, and displaying the measurement results as a spatial distribution will assist in understanding the biological effects of electromagnetic fields. Several methods for visualizing electromagnetic fields have been proposed depending on the scale of the target measurement area. In 2018, Isrie et al. used the GPS to acquire the measurement

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position of the electric field strength radiated from the radar tower and realize the visualization of the electric field distribution over a wide range by using the heads-up display [4]. In 2019, Rioult et al. proposed an electromagnetic compatibility scan system that can visualize the electromagnetic field distribution by setting a sensor and a smartphone on a measuring jig [5]. An accurate measurement position is automatically calculated by integrating the measurement unit and the display unit. It is useful for measuring the electromagnetic field distribution around small devices. In 2020, Guarese et al. realized the visualization of electromagnetic fields on circuit boards and radiation patterns from antennas in anechoic chambers as a visualization of electromagnetic compatibility testing [6]. We have been studying a method for displaying the distribution of electromagnetic fields and reported how to display the electromagnetic field distribution on a two-dimensional plane [7,8] and the spatial distribution using a three-dimensional graph [9,10] or augmented reality (AR) technology [11]. In our previous research, we showed a method of visualizing the electric field distribution by AR technology using a dedicated AR marker printed with 2D geometric patterns [11]. In order to reduce blind spots and implement AR displaying from various viewpoints, we have established a method to confirm a spatial distribution in real-time on a tablet screen by using a cube-shaped marker with attaching AR markers to multiple surfaces of the cube. By observing the coloured objects that represent the strength of the magnetic field from various directions, the three-dimensional distribution became easier to understand. Fig. 1 shows an example of visualization results using a cubic marker. However, since cubic markers need to be prepared separately, more equipment is required for measurement. In addition, since the Bluetooth connection is used for communication between the control PC and the tablet terminal, there was a limitation that only one tablet terminal could be used to display the distribution.

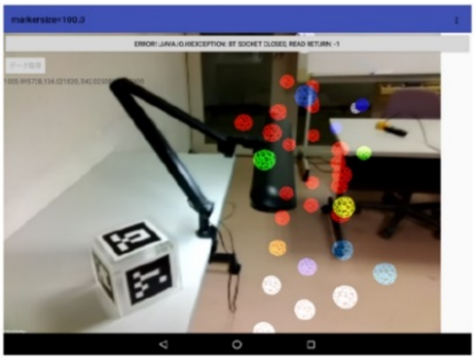

Figure 1. High-frequency electric field distribution using cubic AR marker.

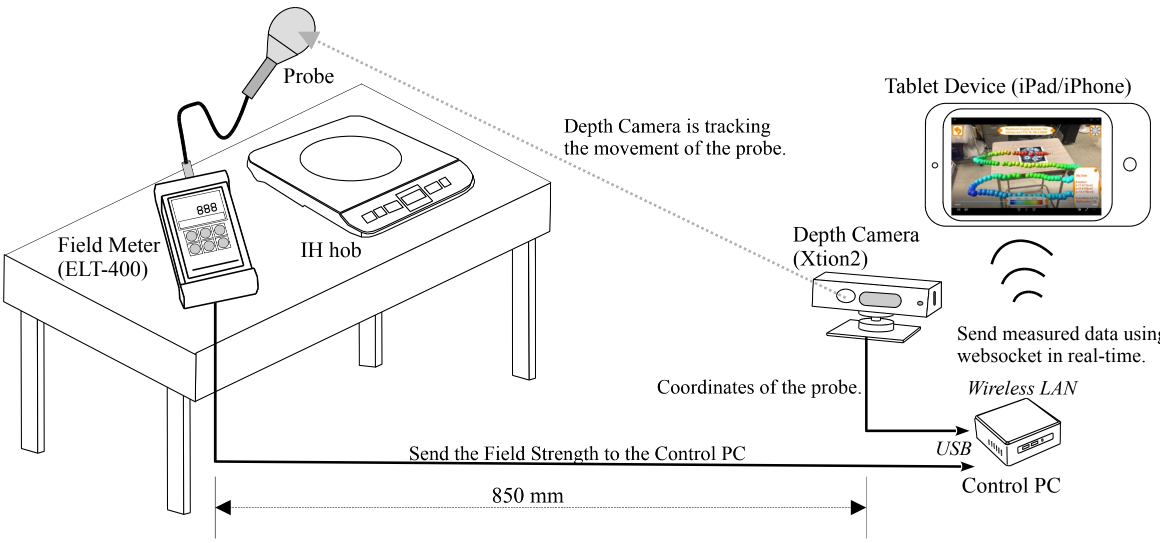

Figure 2. Experimental configuration of marker-less AR.

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In order to solve these problems, we propose the visualization of the electromagnetic field distribution by markerless AR which uses feature points of existing equipment (e.g. the field meter) as a marker without using a dedicated marker. As an AR engine, we examined the AR toolkit [12,13] and the Vuforia [14], which are widely known as a method for marker-less AR. Markerless AR uses feature points extracted from the image as markers. The ARtoolkit provides a method to extract feature points by movement vector from the captured image. However, if the marker cannot be detected from the camera, the coloured objects cannot be displayed on the image, which is a problem for monitoring from various viewpoints. On the other hand, the Vuforia has an Extended Tracking function that can display objects even if the marker cannot be captured from the camera image. Extended Tracking is the concept that a target's pose information will be available even when the target is no longer in the field of view of the camera or cannot directly be tracked for other reasons [15]. Therefore, in this study, we investigated a method for visualizing the electromagnetic field distribution by marker-less AR using the Vuforia as an AR engine.

2. METHOD

The system consists of a measuring section and a displaying section. The system configuration is shown in Figure 2.

2.1. Measuring section

The measurement section acquires magnetic field strength and measurement position. The magnetic field strength is measured by a low-frequency magnetometer and transmitted to a control PC via serial communication using a USB cable. The tip of the magnetometer is tracked by a depth camera to acquire the measurement position as three-dimensional coordinates. Figure 3 shows the appearance of the magnetic field measuring instrument ELT-400 and the depth camera (Xtion2), and the specifications are shown in Table 1. Figure 4 shows a depth view from the depth camera and the tracking result of the tip of the meter. The three-dimensional coordinates of the measuring position and the magnetic field strength are transmitted to the tablet in the displaying section via the WebSocket protocol.

Figure 3. The field meter and the depth camera.

Table 1. Specifications of the equipment.

Field meter	Narda S.T.S ELT-400 Standard: ICNIRP 2010 Frequency range: 1 Hz – 400 kHz
Depth camera	ASUS Xtion2 Resolution: 640 x 480 30 fps Size: 110 x 35 x 35 mm

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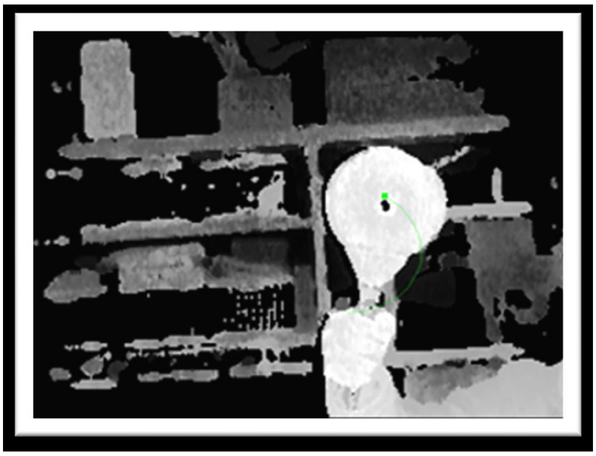

Figure 4. Tracking the tip of the field meter with the depth camera. The camera tracks the center of the probe.

Non-stick sheet. The front panel of the meter

Figure 5. Images used as a marker.

Table 2. Components of the AR Viewer.

Development environment	Unity 2021.3.5f1
AR Engine	Vuforia Engine 10.4
Database type	Device
Target	Single image

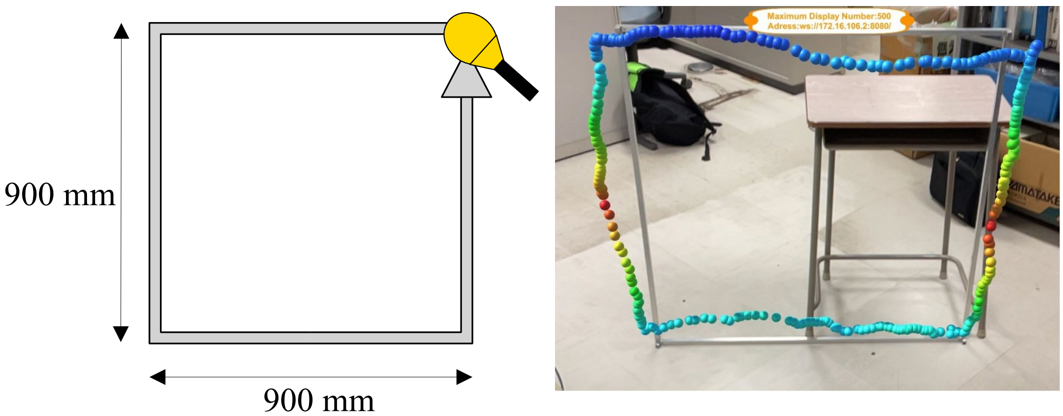

Figure 6. Accuracy evaluation for freehand tracing on a square area. The length of a side is 900 mm.

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2.2. Displaying section

The Displaying section receives the measurement position and magnetic field strength and then displays them on the screen. Unity was used as the development environment, and Vuforia was used as the AR engine [16]. The specifications of the AR viewer application are shown in Table 2. Two types of images were prepared as marker images to be used for AR display: the non-stick cover of the IH cooker and the operation panel of the field meter. Fig. 5 shows the image used as a marker. Registering the images for a marker on the Vuforia Developer Site. This process is necessary to make the image available as the marker from Unity. A non-stick cover is useful for evaluation; however, the surface of the IH hob is covered with a pan, therefore, it is difficult to use the surface pattern of the IH hob as a marker.

Table 3. Specifications of the tablet and smartphone.

Model	Version
Apple Inc. iPad Air 4th Gen.	iOS 15.3.1
Apple Inc. iPhone 7	iOS 14.7.1

Figure 7. Displaying with the tablet (iPad) and smartphone (iPhone).

3. EXPERIMENT

3.1. Error verification of object display position

The accuracy of the displaying position of the object was verified, as shown in Fig. 6. The coordinate error was calculated when a square with a side of 900 mm was traced with the field meter. The average length of the detected size was 924.65 mm, and the error was 24.65 mm (2.74%); the radius of the coloured sphere displayed on the AR screen was set to 25 mm, which means that the error included about half the size of the sphere.

3.2. Displaying on multiple terminals

Since the communication between the measurement unit and the display unit is performed via WebSocket, simultaneous communication with multiple terminals is possible. We built an AR displaying an application for iOS and confirmed it using iPad-Air and iPhone. Each terminal can communicate with the control PC using TCP/IP. The specifications are shown in Table 3, and the display result is shown in Fig. 7. It was confirmed that the magnetic field distribution could be displayed at the same time from each viewpoint using the rear camera of each terminal.

3.3. Magnetic field distributions around the IH cooker

Fig. 8 shows an example of displaying magnetic field distributions around the IH cooker on a tablet screen. The tablet monitors the IH cooker through its camera, and the panel of the field meter is used as a marker then, the magnetic field strength is displayed on the screen as coloured objects. The measurement PC and the tablet communicate with each other using a WebSocket connection, and the tablet receives the measured values in

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real-time from the PC. The tablet receives coordinates and magnetic field strength and then generates a distribution map using these values. While the camera captures the field meter, the measured values are displayed as AR objects. Even if the camera loses sight of the marker, the coloured objects are displayed at the position estimated by the Extended Tracking feature of the AR engine Vuforia, so the measurement can be continued.

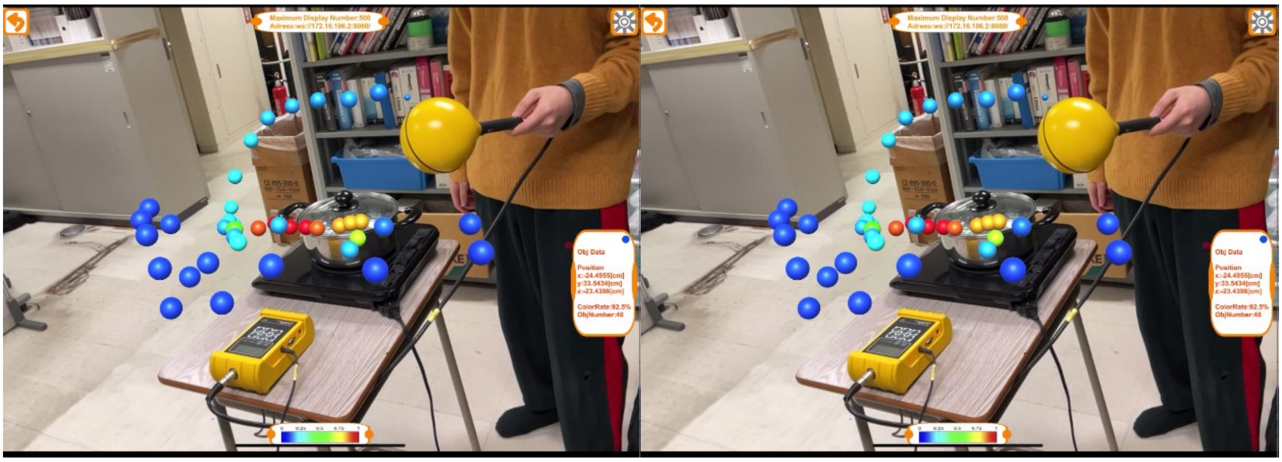

Figure 8. AR displaying results around the IH cooker from different viewpoints.

4. CONCLUSIONS

This study introduced a real-time visualization method for the low-frequency magnetic field using markerless AR. By using an electric field meter as an AR marker, which is indispensable for measurement, it has become possible to measure more easily. In addition, since the results during measurement can be verified in real-time on multiple terminals, the system is expected to be used not only for electromagnetic compatibility testing but also as learning material. In the future, we intend to improve the operability of the system to make it even easier to use for general people.

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