A New 3-D Visualization System of Magnetic Field with Augmented Reality Technology for Education

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***Abstract*— In this paper, we propose a new 3-D visualization system to combine a real experiment and a computer simulation utilizing the Augmented Reality technique. The proposed system indicates a synthetic image of mocks captured by two video cameras and their simulated magnetic field to a student. With the developed visualization system, the student obtains the illustration that the magnetic flux lines look like to exist in the real environment in 3-D space.**

***Index Terms*—Augmented Reality technology, electromagnetics education, electromagnetic field simulation, visualization**

I. Introduction

In electromagnetics education, students learn the concept of a magnetic field through experiments, textbooks, and/or computer simulations [1]-[6]. However, it is difficult for beginners to understand a magnetic field because it needs a lot of time and effort to learn it from experiments and the beginners cannot have its image from textbooks. In addition, it is difficult for the beginners to use a simulation software and what they can get is just a phenomenon in virtual world on computer. Therefore, in electromagnetic education the effective education technique is required.

In our previous study, a visualization system with Augmented Reality Technology for magnetic field in 2-D space has been proposed [7]. The previously proposed system presents a synthetic image of mocks and their simulated magnetic field to users in 2-D monitor. They can easily understand a magnetic field with the developed real-time visualization system in an "augmented real world." However, in the previous system, it was restricted to visualize the magnetic field in 2-D space. Therefore, it is impossible to consider the 3-D distribution of the magnetic field.

In this paper, we propose a 3-D visualization system to combine a real experiment and a computer simulation utilizing the Augmented Reality technique [4]. The proposed system indicates a synthetic image of objects (source materials) captured by two video cameras and their simulated magnetic field to a user. It is unnecessary for the objects to be real, but mock (*e.g*. a painted box). With the developed 3-D visualization system, the user can easily understand the magnetic field in an "augmented real world in 3-D space." Additionally, the system has a user-friendly interface that the user can freely move the mock objects in 3-D sapce. When a student can use the developed system, an effective learning style is highly possible rather than the use of textbooks.

II. The Proposed 3-D Visualization System

Fig.1 shows the overview of the developed 3-D vitalization system. The developed system consists of a head mounted display with two discrete VGA (640 x 480) video cameras, a PC, and colored mock objects (*e.g*. magnets). An image captured with each camera is displayed on the right and left screen of the head mounted display, individually. Therefore a user can recognize a mock in three dimensions. The main procedure of the proposed vitalization system is as follows:

Step 1) Colored three-dimensional mock objects are captured on two digital video cameras which are attached on a head mounted display.
Step 2) Captured objects are identified using image-recognition technique in 3-D space.
Step 3) Magnetic flux lines distribution, which is generated by the identified objects, is computed in 3-D space.
Step 4) The synthetic image of the captured objects and the magnetic flux lines are visualized on the head mounted display.

On the steps 1 and 2, the positions of the mocks for 3-D space are identified in the captured two images by the image recognition technique. The mock's 3-D position, size, and/or angle are identified by the parallax of the two captured images. Here, a red and a blue are registered as a north-pole, a south-pole of the magnet in this paper as shown in Fig. 1.

On the steps 3 and 4, the magnetic flux lines are displayed onto the head mounted display. In the developed system, the Finite Element Method (FEM) is employed as a simulation method of magnetic field generated by magnets. However, in the FEM, it is necessary to divide objects into elements [8]-[10], to set boundary conditions, and to setup the condition of material characteristics. Therefore, with the time-consuming FEM, it is impossible to achieve a real-time simulation to be

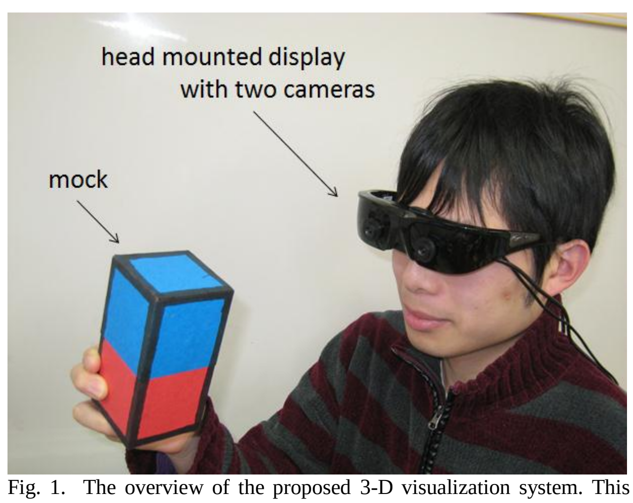

Fig. 1. The overview of the proposed 3-D visualization system. This system is composed by a head mounted display with two cameras, a PC, and some mocks (*e.g*. magnets).

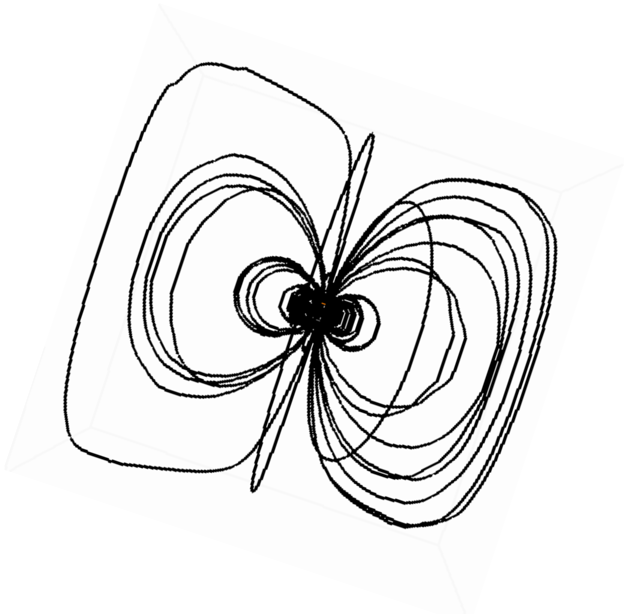

Fig. 2. The magnetic flux lines for 3-D visualization system.

required. In the proposed 3-D visualization system, the magnetic vector potential distribution is computed and prepared on a preprocessing.

In 3-D space, a magnetic flux line equation is given as follows:

$$\frac{dx}{B_x} = \frac{dy}{B_y} = \frac{dz}{B_z}, \quad (1)$$

where B_x, B_y, and B_z are each direction component of magnetic flux density vector calculated with the FEM. As an example, Fig. 2 shows the magnetic flux lines generated by one bar magnet. The calculation method of (1) has been proposed [11]. These procedures are carried out in real-time and the computed synthetic image is represented to the users in real-time. In the developed system the user only have to watch the captured image with the head mounted display. In other words, a student do not need to make any model and any mesh, and to configure any boundary condition for the simulation.

In the proposed 3-D visualization system, the student is able to observe the composite image of the generated magnetic flux line and the real bar magnet in 3-D space with the head mounted display.

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