Real-time Visualization System of Magnetic Field Utilizing Augmented Reality Technology for Education

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Abstract — In electromagnetics education, it is important for beginners to give an image of magnetic field. In this paper we propose a new real-time visualization system. It can visualize a composite image of source materials and their generated magnetic field utilizing the Augmented Reality technique to the users. With this real-time visualization system, electromagnetics learners can observe the visualized magnetic field as a realistic magnetic distribution on real-time and the visualized field changes immediately they move the objects.

I. INTRODUCTION

It is difficult for beginners to understand magnetic field because it is complicated and invisible. Therefore, in electromagnetics education many beginners learn it through experiments and/or computer simulations [1]-[3]. However, the former involves a lot of time and effort, the latter is not easy for the beginners to use a simulation software and it is just a phenomenon in virtual world.

In this paper, we propose 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 a video camera and their simulated magnetic field to users. It is unnecessary for the objects to be real, but mock (e.g. a painted box). With our developed real-time visualization system, the learners can easily understand the magnetic field in the "augmented real world". Additionally, the system has a user-friendly interface that the users can freely move the mock objects (e.g. magnets and coils). In order to verify its usefulness we have applied this system to a few cases.

II. THE PROPOSED REAL-TIME VISUALIZATION SYSTEM

In general, a visualization software for electromagnetic field runs on a PC monitor and the users observe it. Hence especially the beginners are not able to understand the electromagnetic phenomenon enough because it is only visualized in the virtual world environment. Therefore we propose a new visualization and experience system which utilizes the Augmented Reality technique and the visualization technique of the electromagnetic field on real-time. The Augmented Reality technique has been researched and developed as a technology which presents information such as characters and graphics in the real world recently [4]. With adding this outcome to a simulation technique, we have developed a useful visualization system for educating electromagnetics as shown in Fig. 1.

The overview of our developed system is shown in Fig. 2. This system consists of a video camera, a PC and colored mock objects (e.g. magnets and coils). The procedure of the system is as follows:

Step1: The colored mock objects are captured on the digital video camera.
Step2: The captured objects are identified using image-recognition technique.
Step3: The magnetic field distribution, which is generated by the identified objects, is computed.
Step4: The synthetic image of the computed magnetic field distribution and the captured objects are visualized.

Generally, the Finite Element Method (FEM) is adopted as a simulation method of magnetic field generated by magnets, coils and/or electromagnetic materials. In this method it is necessary to divide the objects into mesh, to input the boundary conditions, and to setup the condition of the material characteristics. As a result, the magnetic field distribution is obtained, and it is visualized. Therefore with this time-consuming method it is impossible to achieve a real-time simulation to be required.

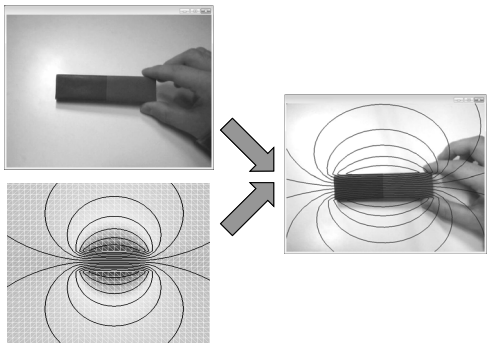

Fig. 1. Real-time visualization system for electromagnetics education.

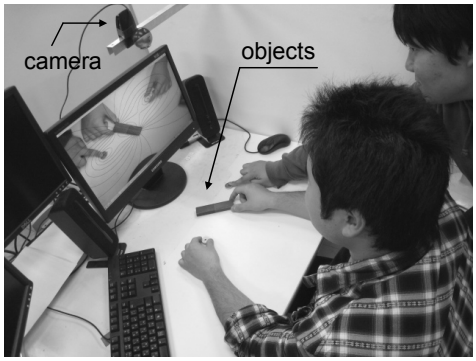

Fig. 2. Overview of the proposed real-time visualization system.

In the proposed real-time visualization system, the magnetic vector potential distribution has been computed and prepared as preprocessing step. In the computation the linear static magnetic field was assumed and the two-dimensional FEM for the magnetic field was adopted. Thus, the computed magnetic flux lines, which are scaled and/or rotated to fit the captured objects, are visualized in real-time. If there are some sources in space, a relative position is calculated and each prepared magnetic vector potential distribution is superposed as shown in Fig. 3. After that, the magnetic flux lines, which are computed from the superposed magnetic vector potential distribution, are visualized in real-time. It enables the users to freely move and/or rotate each object, of course, it enables the users to immediately observe the change of the magnetic field.

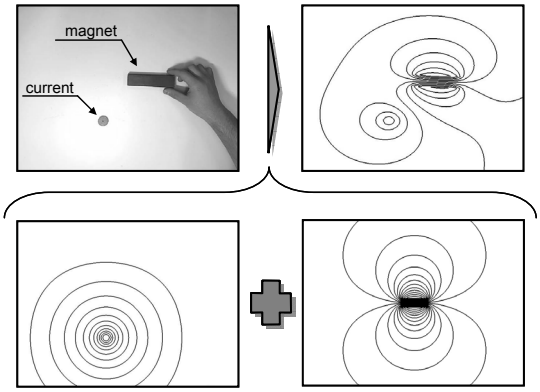

Fig. 3. Each prepared magnetic distribution is superposed for some sources.

III. APPLICATIONS

A. One Magnet model

At first the proposed real-time visualization system was applied to a one magnet model shown in Fig. 4. The system can visualize the magnetic flux lines, additionally the user can change the number of the visualized flux lines. If the user move and/or rotate the magnet with his/her own hand, the appropriate flux lines for any position and orientation of the magnet are visualized in real-time. By this method, the user obtains the illusion that the flux lines look like to exist in the real environment.

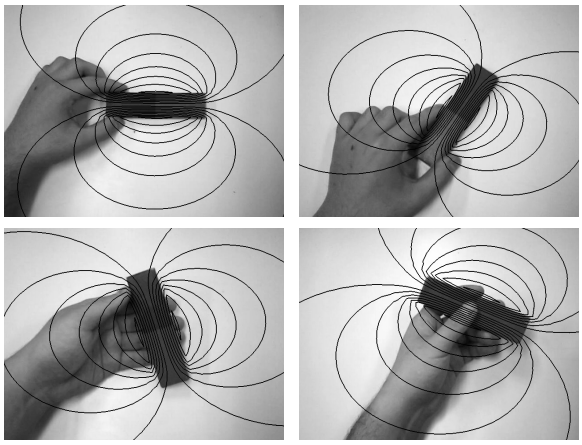
Fig. 4. Execution screens for one magnet model.

B. Magnets and Currents Model

Next the system was applied to a magnets and currents model shown in Fig. 5. In this case, the magnetic field vector potentials generated by some sources interfere each other. In this system, the user can freely and independently change the position of magnets and currents. The user can, in real-time, observe and understand the magnetic field which is caused by the interference.

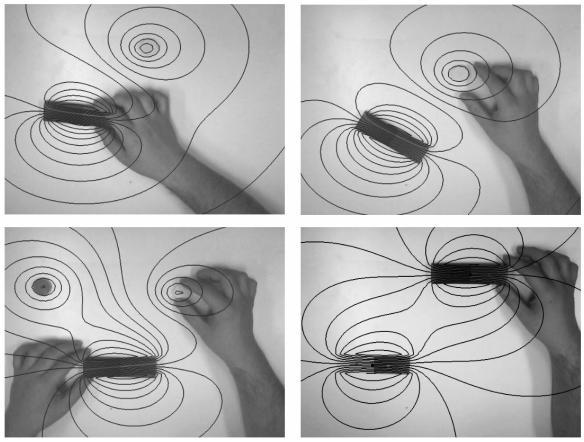
Fig. 5. Execution screens for magnets and currents model.

IV. CONCLUSIONS

We have developed a new real-time visualization system suitable for electromagnetics education. This system is based on the Augmented Reality Technology and the numerical analysis for the electromagnetic field. This system features that one is the ability to visualize the computed magnetic field on the real object, the other is that the position of the objects can be changed by the user's hand. We applied the proposed system to a few models in order to verify its usefulness. To utilize the system, the beginners can easily observe the magnetic field as if the magnetic flux lines were visible.

V. REFERENCES

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