MAT 499
Professor Christopher French

Visualizing Fundamentals of Magnetic and Electric Fields in Virtual Reality

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Introduction

There is one problem that new learners face in learning magnetic and electric fields. They are presented with two-dimensional visualizations when, in fact, these fields are three-dimensional. These visualizations are prone to misinterpretation. For instance, they do not illustrate that these fields fill in the space around a magnet. I aim to tackle this problem by creating immersive experiences in visualizing electric and magnetic fields in Virtual Reality. I harnessed the power of GPU, computer graphics, and virtual reality technologies to create a new way of learning about the two fields that make use of physical movement and gestures in a fun and engaging way. I developed four exhibits, each illustrates magnetic and electric fields in different scenarios.

Definitions

- A magnetic field is a vector field that describes the magnetic influence on moving electric charges [1].
- An electric field is the physical field that surrounds electrically-charged particles and exerts force on all other charged particles in the field, either attracting or repelling them [2].

The Simple Moving Magnet Exhibit

The Simple Moving Magnet Exhibit is the first exhibit that a user encounters when entering the virtual world. The purpose of this exhibit is to give the user a first dive into the theory of magnetic and electric fields. In this exhibit, the user is presented with a magnet that oscillates along the x-axis. As the magnet moves, the user can see a dynamically-rendered field that is computed based on the position of the magnet. The key concept illustrated in this exhibit is how the vector at a certain point in three-dimensional space around the magnet change its direction and magnitude when the magnet moves from one point to another.

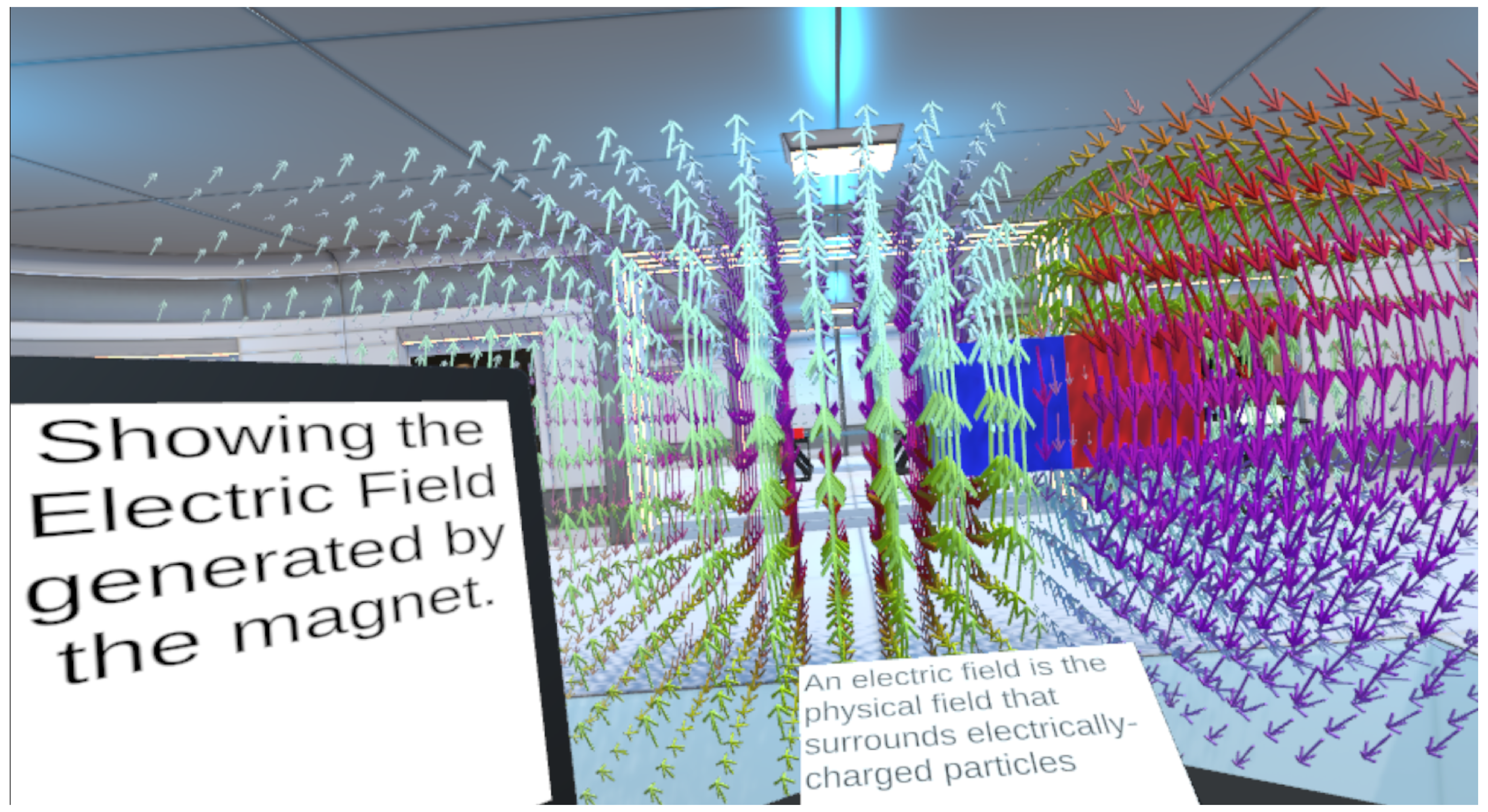

Figure 1: A first person point of view of an electric field.

The user is provided with a tablet and a panel to help them study the key concepts. The user can choose to see either the magnetic field or the electric field by pressing a button on the tablet. The tablet has a pause button which, if pressed, stops the magnet. The tablet is also equipped with a slider that the user can use to position the magnet as they wish. If the slider is slid to the left, the magnet will move in the same direction. While a field is displayed, the user can go to a nearby panel to have a read on the fundamentals of the displayed field.

The Interactable Magnet Exhibit

The purpose of the Interactable Magnet Exhibit is to allow the user to interact with the magnet in a way that gives much more freedom than the first experience. In this exhibit, the user can move the magnet in any direction as opposed to moving it along the x-axis only. The idea behind the creation of this exhibit is once the user has a basic understanding of magnetic and electric fields, they can try to move, rotate, and flip the magnet to see the different visualizations of the magnetic or electric field. The user is presented with a smaller bar magnet placed on a small table. The user can grab the magnet with either their virtual left or right hand. Once the magnet is in the user's virtual hand, they can approach the bigger table where the field of their choosing is located.

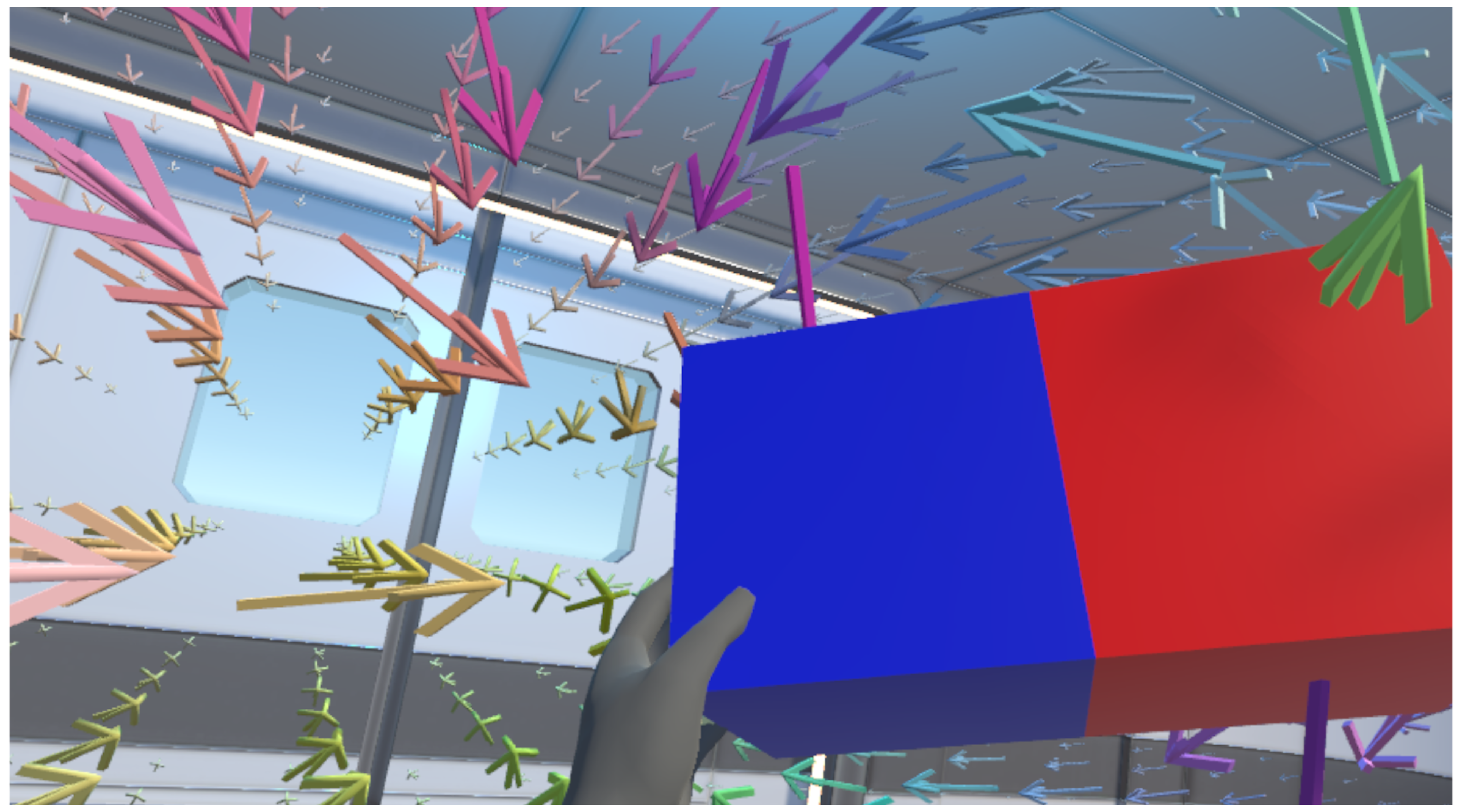

Figure 2: The user is holding the magnet.

The Coil and Magnet Exhibit

The purpose of this exhibit is to recreate a scenario in which the user can carry out an experiment that mimics Faraday's coil and magnet experiment. The difference between this exhibit and Faraday's experiment is that Faraday used a galvanometer whereas the exhibit uses a light bulb to indicate whether there is a flow of current or not. The key idea illustrated in this experience is as follows. When the magnet moves, there is a change in the magnetic field. The change in the magnetic field generates an electric field and results in a flow of current that turns the light bulb on.

Figure 3: When the magnet moves, a current is induced, and the light bulb turns on.

The Two Magnets Exhibit

The Two Magnets Exhibit presents a scenario in which the north pole of a magnet and the south pole of another magnet generate a magnetic field. The purpose of this exhibit is to visualize the changes in the field when a magnet is moving into or away from the other magnet. When the magnet on the left is moved away from the magnet on the right, more arrows will be rendered to fill in the space in between the magnets. The increase in the number of arrows illustrates that magnetic field lines are continuous and exists at any point in space.

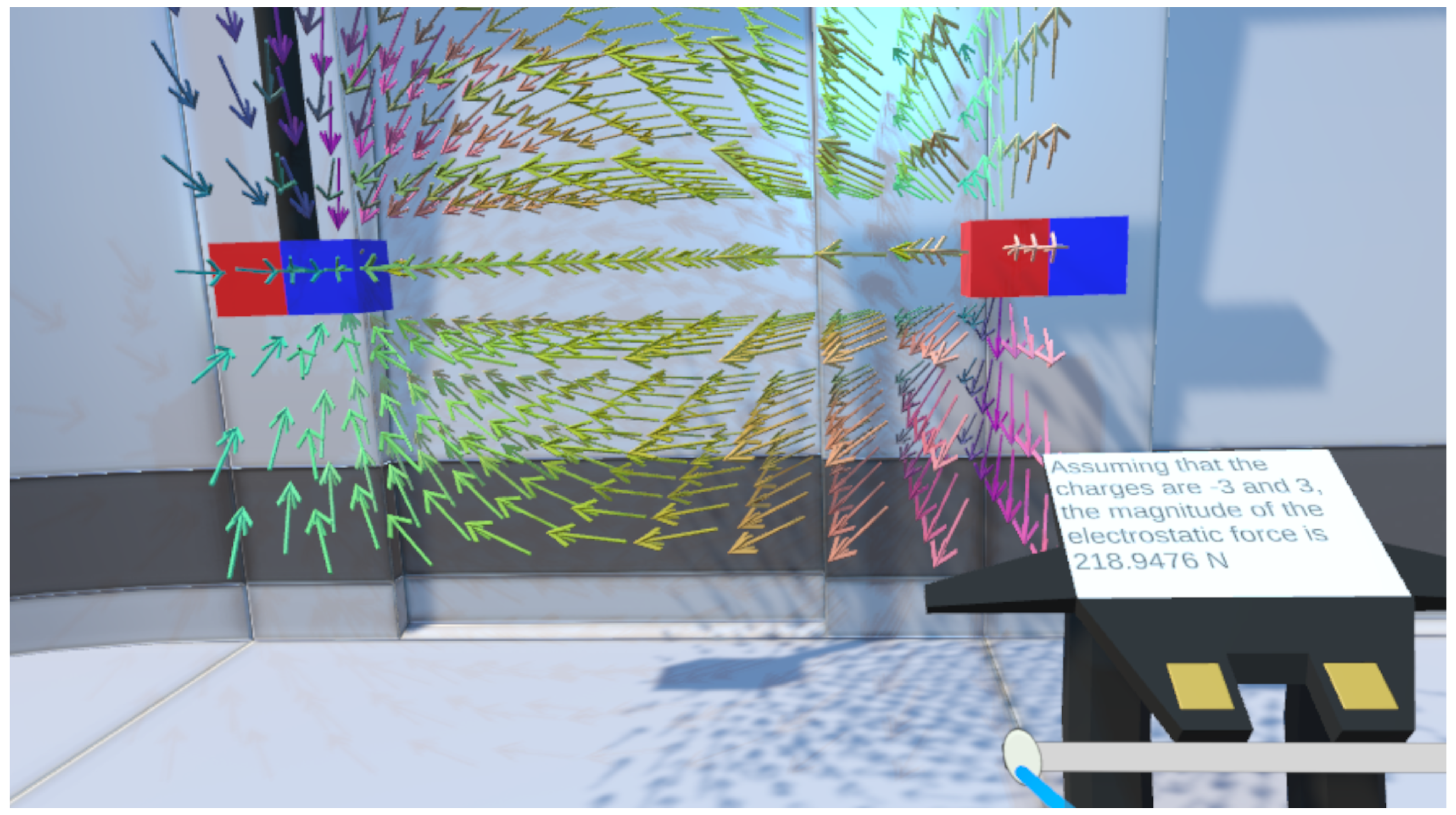

Figure 4: The display of a magnetic field between two magnets.

Acknowledgements

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Future Work

In the coil and magnet exhibit, the code reads in the positions of the magnet in each frame to figure out if it moves or not. If it moves, then the light bulb turns on. I imagined that the light bulb in the exhibit can be made brighter or dimmer depending on the amount of current induced. There is a single integral used to compute the amount of induced current. It will be great if this formula can be implemented in the code to vary the brightness of the light bulb. It will also be great to add more notable experiments carried out by Ampere, Volta, and Couloumb into the virtual world. My hope is that we can

References

[1] Feynman, Richard P.; Leighton, Robert B.; Sands, Matthew (1963). The Feynman Lectures on Physics.

[2] Browne, M. E. (2013). Schaum's outline of physics for engineering and science. McGraw-Hill.