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Haptic Mouse Interface Actuated by an Electromagnet

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***Abstract*— In this paper, we propose a haptic feedback mouse that is actuated by an electromagnet. The haptic mouse works like a normal optical mouse but attraction force is generated between the electromagnet and a ferromagnetic mouse pad. We introduce some examples using the haptic mouse. For example, when the mouse cursor moves into the clickable area, magnetic attraction generates strong friction, allowing the user to find the target easily. In another example, the system gives the user tactile feedback when the mouse cursor passes lines. This would be helpful to increase working efficiency for CAD work and could graphic designers who must perform abundant mouse control to select lines. If this system is integrated into computer games, it can provide the game user with various tactile experiences.**

Keywords- Haptic, mouse, electromagnet, force feedback

I. INTRODUCTION

The mouse has been widely used as input devices of computers. They are used to move cursors and scroll bars by sliding them along a flat surface. By including tactile feedback, the device can become more effective and intuitive.

A number of studies on tactile display of input devices have been reported in recent years. Gi-Hun Yang et al. proposed a tactile display device that provides both pin-array type tactile feedback and thermal feedback [1]. With this device, users were able to discriminate among different materials by considering the temperature variation, which could be sensed as they touched an object's surface. In their subsequent research, they proposed a tactile display mouse [2]. Each tactile display module is comprised of a piezoelectric ultrasonic actuator array. Nadine Baptiste-Jessel et al. presented a method to associate force, voice, and sound feedback with a web browser application and force feedback mouse [3]. Geographical and musical information were applied to train the phase of mouse handling so that the user could make a mental construction of displayed data.

Kermani et al. developed a device that prevents the mouse from falling out of the mouse pad by using electro-magnetic force [4]. This device, however, generates magnetic force only when the user does not touch the device. If the user touches the mouse, the magnetic force is eliminated and the mouse moves without any resistance. Kubica et al. invented a structure that provides resistance force to a mouse when it moves [5]. However, this device is inconvenient, as the complicated structure prevents the mouse from moving freely.

There are studies for the mouse using magnetic attraction between mouse installed electromagnet and ferromagnetic pad. The research of Akamatsu and MacKenzie tested a multi-modal mouse with tactile and force feedback by an actuated electromagnet [6]. They showed that tactile and force feedback tends to reduce the stopping time of mouse cursor in target region. And Schneider et al studied friction feedback between a mouse and a mouse pad using an electromagnet [7]. By applying to friction at the target region, users were able to move the mouse quickly.

In this study, we develop previous mouse studies actuated an electromagnet, and then attempt a variety of applications based on the interaction between the mouse cursor and digital information. Figure 1 shows the haptic mouse interface system and research environment.

II. BASIC THEOREM OF ELECTROMAGNET

For an electromagnet with the single magnet circuit illustrated in figure 2, Ampere's law reduces to where N is the number of wire coils and I is the current of the wire. H represents the magnetizing field intensity and L is the total length of the core or gap. Eq. (1) is a nonlinear equation, as the permeability of the core μ varies with the magnetic field strength B. To obtain an exact solution, the core material hysteresis curve must be derived, as shown in figure 3.

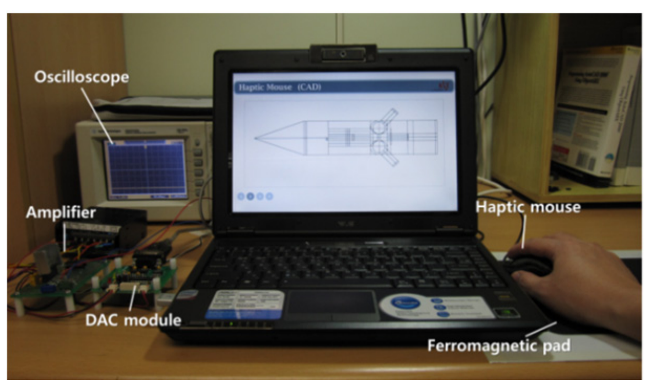

Figure 1. Mouse interface using an electromagnet

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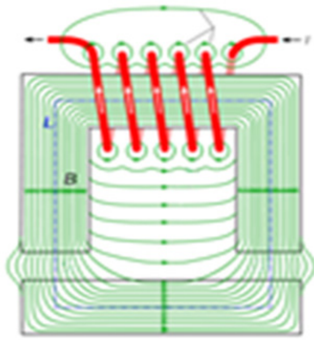


Figure 2. Single magnet circuit

$$NI = H_{core}L_{core} + H_{gap}L_{gap}$$
$$NI = B\left(\frac{L_{core}}{\mu} + \frac{L_{gap}}{\mu_0}\right) \qquad (1)$$

The force exerted by an electromagnet on a section of core material, whose cross section area is A, is

$$\mathrm{F} = \frac{B^2 A}{2\mu_0} \qquad (2)$$

For a closed magnetic circuit, eq. (1) becomes

$$\mathrm{B} = \frac{NI\mu}{L} \qquad (3)$$

Substituting eq. (3) into eq. (2), the force is

$$\mathrm{F} = \frac{\mu^2 N^2 I^2 A}{2\mu_0 L^2} \qquad (4)$$

Therefore, the stronger electromagnetic force can be generated as current of the coil is increased. Design of the electromagnet is also important because the maximum force depends on the cross-section area of the magnet, the number of coils and the length of the magnetizing field loop [8, 9].

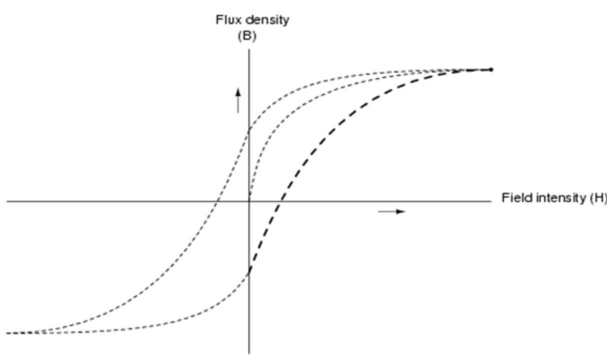


Figure 3. Magnetic hysteresis curve

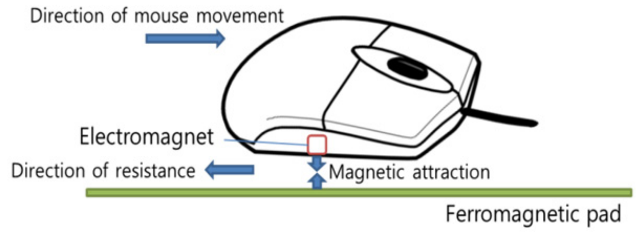
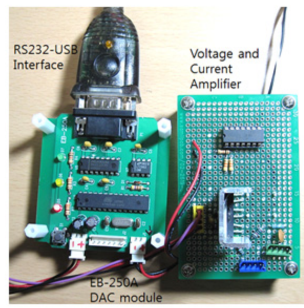


Figure 4. Mouse interface using an electromagnet



(a) DAC module and amplifier circuit

(b) Bottom side of mouse

(c) Mouse installed electromagnet

Figure 5. Prototype implementation

III. DESCRIPTION OF THE HAPTIC MOUSE SYSTEM

Figure 4 provides a conceptual illustration of haptic feedback of a mouse interface using an electromagnet. When voltage is supplied to an electromagnet underneath the mouse, magnetic attraction force is generated between the electromagnet and a ferromagnetic pad. Consequently, resistant force directionally opposite to the mouse movement can be generated. The user can then use the original function of the mouse while sensing various types of physical resistance, which is provided in response to the interaction between the user program and the mouse.

To achieve the purpose mentioned above, a prototype of the mouse interface is made. The DAC (Digital Analog Converter) module, EB-250A, is connected via the USB port on a PC. When an electromagnet operation event occurs on a flash program, the information is sent to EB-250A through the USB interface. The DAC module then generates 0~2.5V analog voltage with 12-bit resolution and operates the electromagnet with 0~24V/0.085A power by using voltage and the current amplifier circuit. Figure 5 (a) shows the DAC module and the amplifier circuit. An electromagnetic holder, JE-3D by Jungwoo magnet, is mounted underneath the Microsoft Arc Mouse, as shown in figure 5 (b). Therefore, haptic feedback via the mouse can be realized while retaining the function of the mouse device. Figure 5 (c) shows the prototype of the mouse with the installed electromagnet.

This input system makes it possible for a user to operate the input device intuitively, obtaining a sense of touch as well in conjunction with visual sensation.

IV. APPLICATION SCENARIO

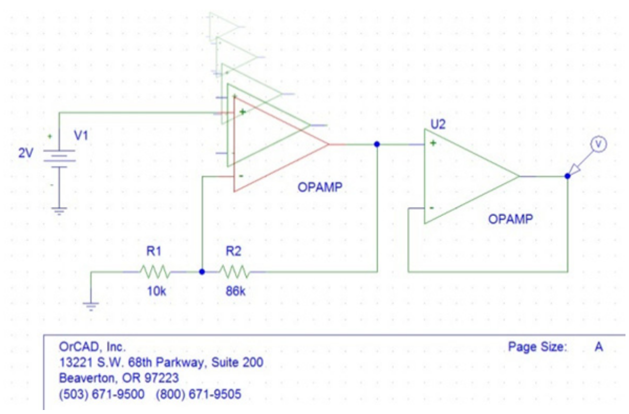
We applied the electromagnetic mouse to some cases, as shown in figure 6.

Figure 6 (a) shows a case of using the mouse on an internet browser. An internet user reads news articles or searches for specific information through an internet browser. The user can move to other web pages by clicking on the links in a current page. In general, the links are perceived through visual cues such as a change of the cursor shape.

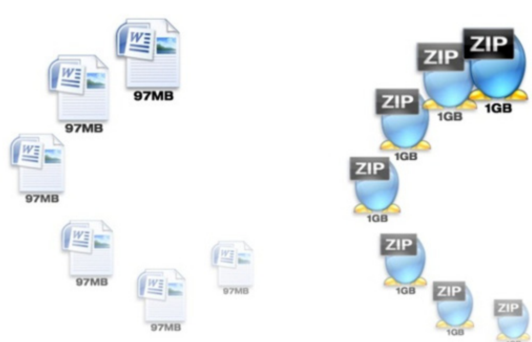
However, we can find the links more intuitively with the proposed electromagnetic mouse. When the cursor passes over the link, the electromagnet generates magnetic attraction force. Therefore, the user can be easily aware of the existing link not only by a visual cue but also with the tactile feedback. Moreover, when a scroll bar included in the internet browser moves up and down, the electromagnet can lend the sense of weight to the moving hand. In the case of a calendar, located on the right side of the internet browser, the user can also intuitively select the year, month, and date. As the cursor is moved farther away from the scroll, the sense of weight decreases and an impulse is provided when the date of the scroll bar is changed. The end of the scroll can be easily recognized by a strong force when the user has scrolled to the end of the bar.

CAD applications are widely used in various fields such as architecture, machinery, computer graphs, and electronic circuitry. These applications typically involve detailed drawing and include complex contents that offer a great deal of information. CAD applications support several convenience functions due to their complexity. A magnet effect is a function that offers visual sensation by attracting objects in the manner of magnet when an object is close to another object or a border. This effect can be maximized with the proposed electromagnetic mouse. Figure 6 (b) shows a case of using the mouse on a CAD application. When the user moves objects or shapes, tactile feedback informs the user that the objects are aligned in a line. This feedback makes it possible to work without grid lines. Moreover, in the area where lines are placed closely, tactile sensation can help the user discern a line from the background. With the tactile feedback, the user can save time and effort for understanding complicated drawings.

(a) Internet browser



(b) Cad application



(c) Dragging icon

Figure 6. Examples of application

Figure 6 (c) shows that the tactile feedback can also be used for dragging icons. The tactile feedback is given to the user according to the size and type of the icon. For example, a larger size icon has more weight, which is generated by the electromagnet, than a smaller size icon, and the icon provides detent tactile feedback if the icon is a word processor document. Thus, the user can perceive the size and type of the document intuitively.

These electromagnetic applications are realized with flash action script. Each event has 12bit strength of the magnet and is sent to the DAC module through the USB interface.

V. FURTHER WORK

Currently, one electromagnet is used in the mouse. However, several electromagnets would be necessary in order for the user to experience the sense of touch in 3D. In future work we will attempt to provide the user with a 3D sensory experience when passing the cursor over a 2D image. A user study will be carried out after implementing various types of haptic profiles.

VI. CONCLUSION

An electromagnet is installed underneath a mouse applied for general use in PCs. The mouse interface is not inconvenient in any way and the original functionality of the mouse is preserved. The electromagnet also offers fast response and affordability. The user can sense tactile feedback as well as audio-visual feedback. With this device, a more intuitive and realistic computing environment may be possible.

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