MagNail: Augmenting Nails with a Magnet to Detect User Actions using a Smart Device

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ABSTRACT
In this study, we design and implement MagNail, a nail augmented with a magnet, that allows user actions to be detected via the magnetic sensor integrated in smart devices such as a smartphone or a tablet PC. By using this system, therefore, the user can intuitively use the smart device using finger motions. We also develop a drawing application with an intuitive mode switching function and evaluate its performance.

Author Keywords
Fingertip; Magnet; Magnetic Sensor; Nail; Smart Device; Wearable;

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g., HCI): Miscellaneous

INTRODUCTION
Some studies have investigated implanting devices such as sensors and tags inside the user's body so that the user can keep the device at all times; examples of such applications include a person with a pacemaker or a microchipped pet. However, implants are impractical because they impose a heavy burden on the human body.

As a safer alternative, we propose *body-attached computing*, in which devices are placed on the nails, teeth, or hair because these are the only places on the human body where it would be painless to do so. Among these parts, fingernails are the most promising sites because they are easily accessible for installation and maintenance. Furthermore, they can be used to indicate the most important human gestures, i.e., hand gestures, associated with everyday human activities. In addition, nail art[1], in which nails are decorated with artificial objects, have become popular with both genders recently. Therefore, in this study, we investigate whether human

[1]A method for forming and coloring nails using ultraviolet-cured acrylic resin (gel) that has been in vogue since around 2006, which is referred to as "nail art" in this study.

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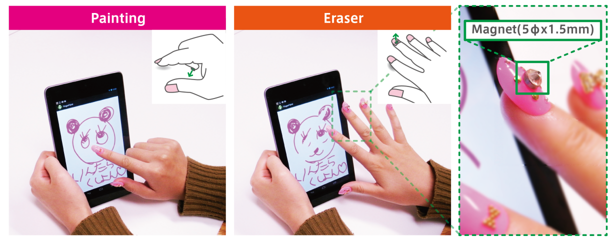

Figure 1. MagNail Paint Application with pen/eraser mode switching via MagNail, which is attached to the middle fingernail. The arrows indicate the magnetic lines.

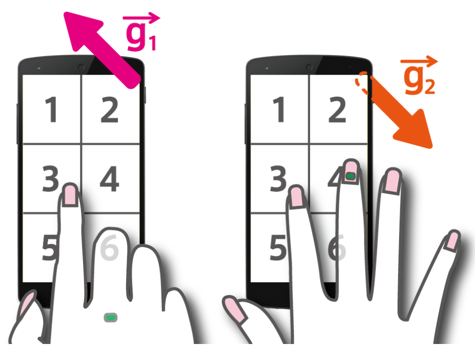

Figure 2. The direction of the middle finger is detected by the magnetic sensor embedded in the smartphone.

nails can serve as a new frontier for safe wearable devices and develop practical HCI devices for use in daily life by placing them on nails as physiologically and socially acceptable accessories.

In this study, based on the concept of body-attached computing, we develop MagNail, which recognizes the finger status of users via an attractive-looking magnet attached to the user's nail as a part of ordinary decorations, such as a jewelry stone used for producing nail art, without requiring any batteries and wires (Figure 1). Magnets are featured in some recent studies to interact with smart devices, such as smartphones and tablet PCs: MagiTact introduces an interaction method using a magnet [2], and MagPen uses a pen-type device with a built-in magnet [1]. Although we also use the magnetic sensor integrated in most smart devices, our MagNail is a kind of wearable device to detect gestures or postures of user's fingers and users do not have to hold any physical devices such as a pen, for facilitating more natural and useful interactions. Statuses of fingers that do not touch the input surface can be also detected.

MAGNAIL

MagNail is a magnet that is applied to a user's nail in the form of nail art. The magnetic field generated by the magnet can be detected by the magnetic sensor integrated in most smart devices for detecting Earth's magnetic field. The magnitude and direction of the magnetic lines detected by the magnetic sensor vary. These different results could be utilized as a user interface.

Implementation

We have developed a prototype to demonstrate the possibility of interacting with MagNail. A small neodymium magnet (5mm diameter × 1.5mm thickness) was used as the material, which was placed on the right middle fingernail of a woman as a subject. An Android smartphone (ASUS Nexus 5) was used as the touch input device. This smartphone has a magnetic sensor, and prototype applications were developed to operate on it.

This smartphone has a three-dimensional magnetic sensor in its upper corner when the display is set to portrait mode. We placed MagNail on the right middle finger of the subject, and measured values of the magnetic sensor while touching six areas of the divided display using the first finger, where the middle finger was bent (Figure 2(left)) or stretched (Figure 2(right)). Then we compensated the Earth's magnetism, and obtained the normalized direction vectors $\vec{g_1}$ and $\vec{g_2}$ of magnetic lines at the sensor, for each bending and stretching finger status. Using the direction vectors, the middle finger's status could be discriminated by calculating

$$f(n) = (\vec{G_x} - \vec{G_0}) \cdot \vec{g_n} \tag{1}$$

and by comparing the scalar values of $f(1)$ and $f(2)$. In this formula, vector $\vec{G_0}$ is the background magnetic vector where the smartphone is placed, and vector $\vec{G_x}$ is the measured magnetic vector by the magnetic sensor.

As an example application based on the discrimination of the middle finger's status using MagNail, we developed the MagNail Paint Application (Figure 1). This is a paint application in which a user with MagNail placed on the middle fingernail performs a drag operation using the first finger as a pen and an eraser while the middle finger is bent and stretched, respectively. Figure 3 shows the average for 50 times of raw magnetic sensor values acquired by Android API, for each bent and stretched middle fingers with a magnet while the first finger is touching each display area. Background Earth's magnetism is not compensated in these results.

Evaluation

We conducted a performance evaluation of the MagNail Paint Application, which used the normalized direction vectors $\vec{g_1}$ and $\vec{g_2}$ obtained from the subject data. To confirm the precision when detecting the user's finger status, we recruited 10 women and we explained the basic usage of MagNail. All of the users experienced MagNail for the first time. We asked each user to place MagNail on the right middle fingernail and to draw and erase something in each of the six areas five times (Figure 2).

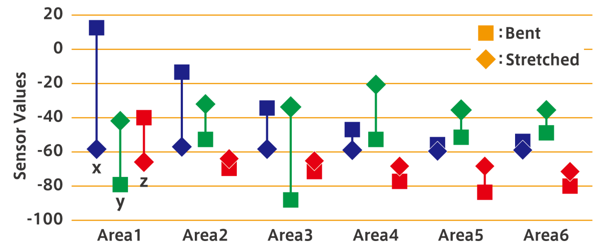

Figure 3. The Average of magnetic sensor values (x, y, z) for each bent and stretched middle fingers with a magnet while the first finger is touching each display area.

Table 1. Accuracy (%) obtained when discriminating the pen mode and eraser mode in each display area.

Area	1	2	3	4	5	6
Pen (bent status)	98	94	88	70	70	66
Eraser (stretched status)	94	92	98	96	98	96

Table 1 summarizes the results of this evaluation in percentages, which show that the eraser mode (stretched status) was operated successfully. However, the pen mode (bent status) did not perform as well. This was because all users held their hand in a stretched status correctly most of the time, whereas the bent status was adopted differently. We could make adjustments for individual hand shapes using a machine learning function. In addition, we found that the bottom areas produced more unstable magnetic values than the upper areas, as expected. This was because the middle fingernail of the bent status is further from the magnetic sensor than the stretched status. However, we found that the resulting magnetic value from MagNail could be detect around the smartphone, even on the bottom areas. Thus, our system could possibly be applied to other applications.

CONCLUSION

In this study, as a body-attached computing application that can serve as a safer alternative to an implant, we developed a durable system for detecting the status of a finger with a magnet fixed to the nail via the magnetic sensor integrated in smart devices. We converted the magnet into a wearable and fashionable system by decorating it in an attractive manner as a nail art component, which was fixed to a user's nail. We are currently developing various additional applications using MagNail.

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REFERENCES

1. Hwang, S., Bianchi, A., Ahn, M., and Wohn, K. Magpen: Magnetically driven pen interactions on and around conventional smartphones. In *MobileHCI '13*, ACM (2013), 412–415.

2. Ketabdar, H., Yüksel, K. A., and Roshandel, M. Magitact: Interaction with mobile devices based on compass (magnetic) sensor. In *Proceedings of the IUI '10*, ACM (2010), 413–414.