FieldSweep：永久磁石の配列とスマートフォン磁気センサを用いた二次元トラッキング手法

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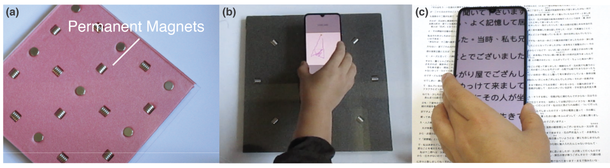

Figure 1: (a)A magnets arrangement used for FieldSweep system. (b)The tracking. (c)Application example (Magnifying glass).

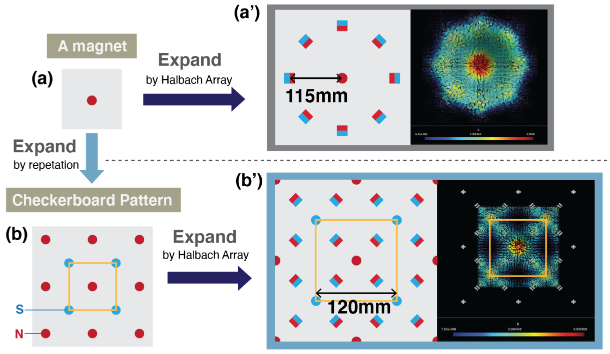

Figure 2: Magnet patterns proposed in our method.

1 INTRODUCTION

Our lives are filled with information. Information provided in public places, such as station signs, maps, school bulletin boards, and billboards, is often printed on paper or boards and displayed on a flat surface. In recent years, the price of LCDs and projectors has decreased, and more and more information is presented via digital signage. For example, many information boards and vending machines with touch panels have been installed in cities.

Many of these interactive systems are based on the use of hand and finger movements. Therefore, there is a growing demand for technology to detect the motion of objects on a plane. In the past, capacitive touch panels, cameras, and infrared sensors were mainly used for this detection. However, they are expensive and require a power source, making it difficult to deploy them ubiquitously.

In this paper, we propose FieldSweep, a tracking method on a flat surface using only permanent magnets and a smartphone. This method tracks the position of the smartphone as it slides above the permanent magnets (Fig.1). The basic mechanism is to measure the magnetic field created on the plane by the permanent magnets using a three-axis magnetic sensor on the smartphone, and to estimate the relative position to the magnets from the three-dimensional vector of the measured magnetic field lines. Since only a permanent magnets and a fixing plate, such as an acrylic plate, are used on the plane side, no electronic components or power supply are required.

2 FIELDSWEEP

2.1 Tracking Principle

In FieldSweep, we first store the magnetic vector field data of the plane above the magnets. The magnets are configured in a specific pattern. The data is a two-dimensional array of three-dimensional vector values. Next, we construct the actual magnet configuration and place a smartphone on the plane at a distance corresponding to the simulation. Then we measure the directional vector of the magnetic field using the built-in three-axis magnetometer. The angle of the measured vector is compared with the simulated data. The location of the data with the closest angle is considered as the position of the magnetometer. The closeness of the angle is indicated by the cosine similarity between the simulated vector and the measured one.

2.2 Magnets Arrangement

In our method, the sensor is calibrated with the ambient magnetic field because it constitutes noise in the measurement. The ambient magnetic field is measured before tracking starts, and its value is subtracted from the measured value during tracking. Therefore, the intended magnetic field by the magnets should be sufficiently larger than the ambient magnetic field, to perform stable measurement. We perceived that an approximately 2 times stronger magnetic field is needed for stable tracking through our study. Thus, it is desirable that the magnets are arranged so that the magnetic field intensity is large enough all around the tracking field.

Furthermore, the magnetic vectors must be in different directions at each location to uniquely determine the position. To achieve stable tracking by this method, the magnets are placed with these two points in mind.

In order to expand a single magnet's magnetic field pattern to a large area, we considered two types of extension method. One method is the repetitive expansion shown in Fig.2(b) and (b'). By arranging the magnets in a checkerboard pattern with the N and S poles facing forward, the magnetic field area that can be measured with a smartphone can be extended to a larger area (Fig.2(b)). Here, the yellow square in the figure is one unit, and the magnet arrangement is repeated left to right, and up and down. Hereinafter, this unit is referred to as a repetitive unit. The repetitive units have exactly the same magnetic

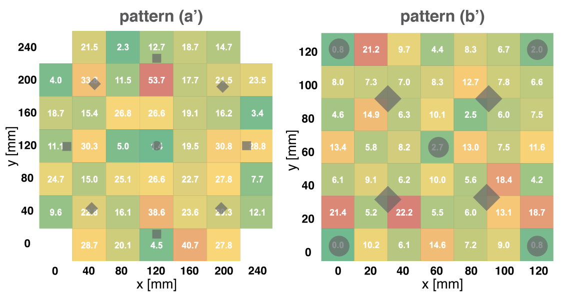

Figure 3: Results of accuracy evaluation. The average error [mm] for each grid point is shown. Pattern (a') on the left and pattern (b') on the right. The black figures show the magnet position.

field pattern, so the magnetic vector can be unique only in one repetitive unit. Therefore, the absolute position can only be estimated within this one unit.

Furthermore, we assumed that we can use a magnet array called a Halbach array[4] to expand the range of the magnetic field further. In the Halbach array, a horizontal magnet is inserted between each magnet. The magnetic field on the top surface is enhanced by the interference of the vertical and horizontal magnets. We used this idea to expand a magnetic field further, for Fig.2(a) and (b) each. They are shown in Fig.2(a') and (b'), respectively. In the following, we refer to them as pattern (a') and pattern (b'), respectively.

In pattern (a'), a single magnet's magnetic field was enlarged to a circular pattern. The magnets are placed horizontally to strengthen the magnetic field on the upper surface, using the idea of the Halbach array.

In pattern (b'), we used the Halbach array again to expand the size of one repetitive unit of the checkerboard pattern. A horizontal magnet was placed between each of the upward-facing magnets. This arrangement generates a sufficient magnetic field on the tracking surface even when the magnet spacing is widened. As a result, the repetitive unit range can be large, compared with a simple checkerboard pattern.

2.3 Tracking Accuracy Evaluation

We conducted an experiment to evaluate the accuracy of the tracking for patterns (a') and (b').

We prepared a grid of points with 40mm spacing for pattern (a') and 20mm spacing for pattern (b') from edge to edge of the board, and measured the distance between the estimated position and the actual position at each point.

The initial position was arbitrarily selected from the measurement target area. After the initial position estimation, the smartphone was moved so that the sensor of the smartphone was positioned directly above the grid point to be measured, and the position was estimated. The above procedure was carried out five times in total.

The error (the distance from the original coordinates to the measured point) averaged over all trials for each grid point is shown in Figure 3. In pattern (a'), the average error over the entire area was 27.6mm, and in pattern (b') it was 11.1mm. The errors for one side of the measurement area were 12% for pattern (a') and 9% for pattern (b'), which means that the position could be detected with an error of about 10% each.

3 RELATED WORK

Various technologies have been developed for tracking and input using magnets. In particular, permanent magnets, which do not require a power source and are inexpensive, are often used in human-computer interaction (HCI) research because they are easy to use and readily available[3][1].

Also, various techniques for two-dimensional tracking have been studied. For example, optical sensors, cameras, or capacitive sensors are used. These methods require a power supply and installation cost.

Some methods use hand-held machines or sensors for tracking, like our method. For example, mechanical and optical mouse methods have been proposed for interaction to detect object movement. However, since these methods can only estimate relative movement, the initial position must be specified. Some research used a capacitive touch panel or an LCD to track mobile devices on a planer surface[2]. Our method does not require special patterns for the surface and only requires a smartphone as the handheld machine.

4 CONCLUSION

This paper presents FieldSweep, a two-dimensional tracking method using only a smartphone and inexpensive permanent magnets. This method requires no external power supply, no electronic components, and no attachments to the smartphone.

References

[1] Ke-Yu Chen, Kent Lyons, Sean White, and Shwetak Patel. UTrack: 3D Input Using Two Magnetic Sensors. In *Proc. of UIST*. 237–244.

[2] Sang-won Leigh, Philipp Schoessler, Felix Heibeck, Pattie Maes, and Hiroshi Ishii. 2015. THAW: Tangible Interaction with See-Through Augmentation for Smartphones on Computer Screens. In *Proc. of TEI*. 89–96.

[3] Rong-Hao Liang, Kai-Yin Cheng, Chao-Huai Su, Chien-Ting Weng, Bing-Yu Chen, and De-Nian Yang. 2012. GaussSense: Attachable Stylus Sensing Using Magnetic Sensor Grid. In *Proc. of UIST*. 319–326.

[4] J. Mallinson. 1973. One-sided fluxes – A magnetic curiosity? *IEEE Transactions on Magnetics* 9 (1973), 678–682.