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Abstract

In our research we proposed a wearable handwriting input device using magnetic field. This device requires mounting a permanent magnet onto fingertip and detecting the magnetic field generated by the magnet through magnetic sensors at the wrist of the other hand. The position of magnet is calculated by the vector of the magnetic field with geomagnetism cancellation. We made prototype device and succeeded to get the handwriting input character. The influences of misalignment of magnet and noise in circuit are investigated by simulations and experiments.

1. Introduction

As information technology was developed quickly, many kinds of input devices have been developed. They make our lives much more comfortable and convenient. On the other hand, these devices have many disadvantages. For example, keyboard is too big to carry and requires training to get used to it. Mouse needs a plane to operate. Touch panel is good but requires a panel to work on, and its working space is limited within the panel. Virtual keyboard needs a plane to put user's hands and has to be fixed somewhere. Voice input has been developed greatly but it does not work well in noisy environment and needs much time to be used to it. And for elder person, post-natal visually impaired and those who are not skilled in operation of computer, few devices are available. Further more, few devices are developed for the wearable computing.

Therefore we have proposed a new device to fit the demand above. It is able to be used by almost everyone, including post-natal visually impaired, people who are not used to computer, and those working in noisy environment. This device does not need any plane or panel, just needs to be fixed onto user's hands. And user can be used to it without any training even user get it just now.

2. Proposed device

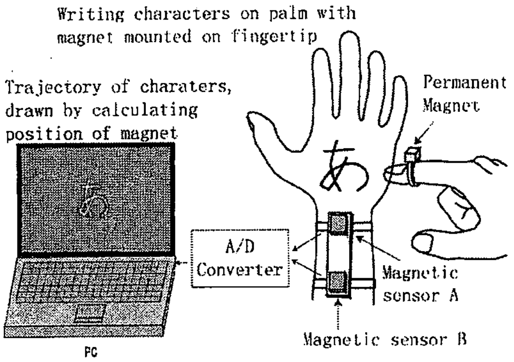

Fig.1 Image of proposed device

Fig.1 shows the whole image of our device. The input device we proposed consists of a permanent magnet which is mounted on user's finger, two magnetic sensors and their peripheral circuits to detect the magnetic fields generated by the magnet, an A/D converter which converts the output voltage signal of magnetic sensor into digital one to input to computer, and a computer to calculate the position of magnet and visualize the handwriting character.

3. Positioning calculation

Before calculating the position of magnet, we need to know the magnetic field generated by it. Magnet locates at (x, y) in magnetic sensor oriented coordinate will generate magnetic field which can be gotten by Eqs.(1)-(2). Its image is shown in Fig.2

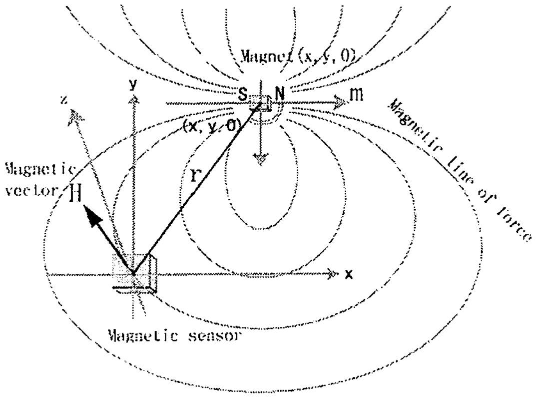

Fig.2 Magnetic field generated by magnet

$$\mathbf{H(r)} = \frac{K}{r^3}\left[\frac{3\mathbf{r}(\mathbf{m}\cdot\mathbf{r})}{r^2} - \mathbf{m}\right] \quad (1)$$

Here **m** is the unit vector of magnetic moment of magnet, which should be m(x, y, z). m is the magnetic moment of magnet. **r** is the location vector of magnet, and its value is r, the distance between magnet and magnetic sensor.

When the magnet locates at (x, y, 0) in the magnetic sensor oriented coordinate, **m** should be (1, 0, 0), and **r** should be (-x, -y, 0).

$$(H_x, H_y, H_z) = \left(K\cdot\frac{2x^2 - y^2}{(x^2+y^2)^{\frac{5}{2}}},\ 3K\cdot\frac{xy}{(x^2+y^2)^{\frac{5}{2}}},\ 0\right) \quad (2)$$

In our device we adopt two magnetic sensors to detect the position of magnet with geomagnetism cancellation. The position of magnet can be yielded by the following equations through the difference of outputs of two magnetic sensors. Relationship between magnet and outputs of two magnetic sensors is shown in Fig.3. They can be yielded by Eqs.(3)-(4)

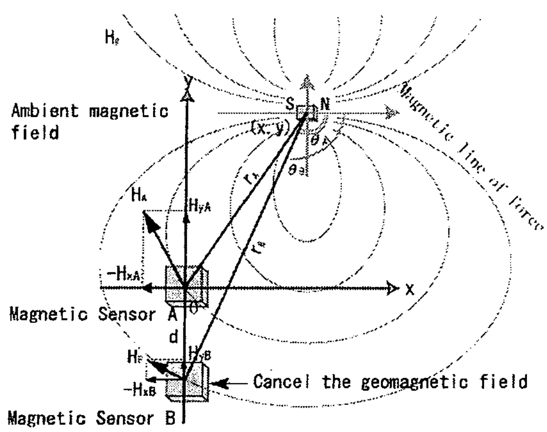

Fig.3 Image of positioning calculation

$$f_x(x,y) = K\cdot\left\{\frac{2x^2-(y+d)^2}{[x^2+(y+d)^2]^{\frac{5}{2}}} - \frac{2x^2-y^2}{(x^2+y^2)^{\frac{5}{2}}}\right\} \quad (3)$$

$$f_y(x,y)=3K\cdot\{\frac{x(y+d)}{[x^2+(y+d)^2]^{\frac{5}{2}}}-\frac{xy}{(x^2+y^2)^{\frac{5}{2}}}\} \quad (4)$$

Here, K is the coefficient about magnetic moment in our device. (x, y) is the position of magnet in magnetic sensor A oriented coordinate. d is the distance between two magnetic sensors.

Because it is difficult to solve equations (3)-(4), we adopt steepest descent method (SD-method) in our system.

In SD-method calculation starts at an arbitrary point (x_0, y_0). We take a series of steps until we are satisfied that we are close enough to solution. When we take a step, we choose the direction of (f'_x, f'_y). And we assume that the target function is:

$$F(x,y)=f_x^2(x,y)+f_y^2(x,y) \quad (5)$$

Firstly we select an arbitrary point (x_0, y_0), and calculate the target function. Then we will compare with the value of target function and e, where e is the accuracy parameter. If F(x_0, y_0)<e, then the calculation is over and we find the result. If F(x_0, y_0)>e, we will go to next step.

The k+1 (k=0, 1, 2, …, n) step can be yielded by following equation:

$$\begin{bmatrix} x_{k+1} \\ y_{k+1} \end{bmatrix} = p\cdot\frac{F(x_k,y_k)}{F_x^2(x_k,y_k)+F_y^2(x_k,y_k)}\cdot \begin{bmatrix} F_x(x_k,y_k) \\ F_y(x_k,y_k) \end{bmatrix} + \begin{bmatrix} x_k \\ y_k \end{bmatrix} \quad (6)$$

Here F_x, F_y are the partial differential of target function F(x, y). p is a parameter of steepest method, which can control the speed of convergence. The calculation should be continued until the target function F(x, y) <e.

We select (0, 0.001) as the initial point in SD-method and p is 2, e is 1e-3 in our device.

3. Prototype device

2-axis magnetic sensor Honeywell® HMC-1022 is adopted in our device. We exploit Interface® CBI-3133B as A/D converter. Neodymium type magnet Tsuchino® 51-421 is selected to mount onto user's fingertip. We designed a mounter for it. C&D Technologies® NMA0505S is used in our device as power supply module. The PCB of our device is shown in Fig.4. A/D converter, power supply module and computer are not included in the photos. The PCB is mounted on the wrist by a mounter.

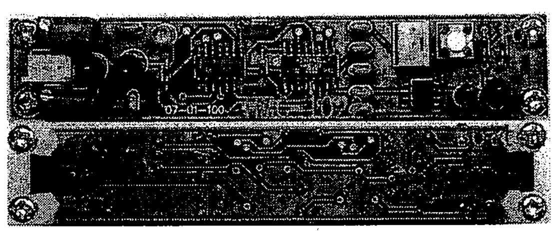

Fig.4 Photos of prototype device

4. Input handwriting characters

We exploit a regulated DC power supply Nippon Stabilizer Industry® MSA18-5 to do experiments. We did experiments to get the value of coefficient K. Finally we find its value as 0.00031.

After that we try to get the handwriting input character. And the result is shown in Fig.5.

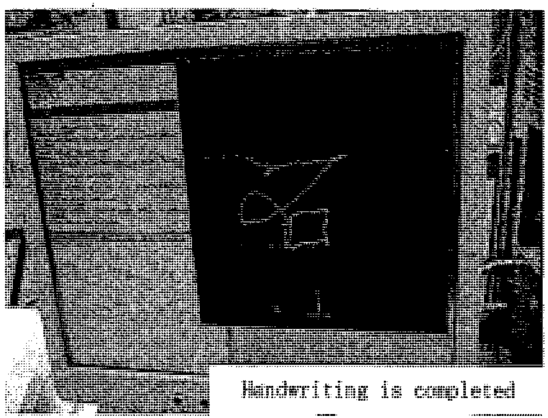

Fig.5 Inputted handwriting character

We did experiment to investigate the position accuracy of our device. Here magnet is set to 30 points in the rectangle with the corner of (-0.04, 0.05) and (0.04, 0.15) [m]. Then we try to get its position by our device. Real positions and experimental results are shown in Fig.6. When geomagnetism cancellation works, the maximum error of position of magnet is about 10mm at the upper corner of the rectangle, which is evidently smaller. It will not confuse us in handwriting input at all.

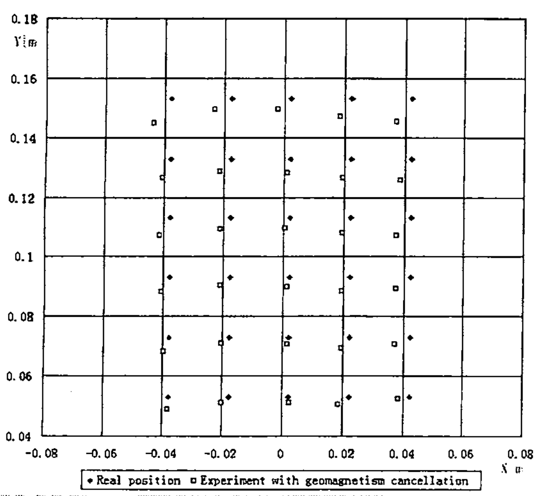

Fig.6 Experimental result

5. Misalignment of magnet

As the magnet is mounted on user's finger in our device, during usage it is difficult to keep the parallel relationship with the magnetic sensors. Maybe it will rotate around y, z axis, or offset and incline from the plane of magnetic sensors. Properly it also may rotate around x axis, but it will not bring any errors because of the characteristic of magnetic field generated by the magnet.

We investigated these four kinds of misalignment of magnet by simulations and experiments. Finally we found that rotation around z axis will bring great error to inputting result. When the misalignment angle which is around z axis increases, the error becomes much bigger, proportionate with the distance between magnet and magnetic sensor. It will confuse us much if the misalignment angle is too big. So rotation of magnet around z axis should be avoided during usage. The example of misalignment is shown in Fig.7.

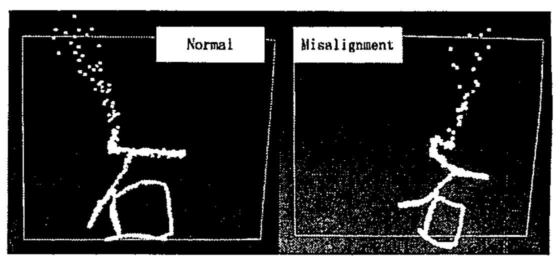

Fig.7 Comparison of normal input and misalignment input

6. Noise in circuit

In order to make our device compact, we have to decrease the distance between two magnetic sensors. However, as the position of magnet is calculated by the difference of outputs of sensors, we have to keep this difference bigger than noise in our circuit. Therefore, we did experiments to know the range of noise in the circuit, and it is shown in Table.1.

Table.1 Range of noises

Range(+/-)	X axis	Y axis
+(V)	0.006274	0.008984
-(V)	-0.010815	-0.005664

During usage the furthest point in the palm is supposed to be (-0.06, 0.13) or (0.06, 0.13) [m]. From Eqs.(3)-(4) we conclude that the minimum theoretical distance between two sensors should be 18.5mm.

7. Conclusion

In this research we succeed to make a prototype handwriting input device using magnetic field. SD-method is proved to be useful to calculate the position of magnet. We succeed to input handwriting characters by our device. Misalignment and noise in device are investigated.

学位論文審査結果の要旨

平成20年7月31日に第1回学位論文審査委員会を開催し，提出された学位論文及び関係資料に基づき論文内容を詳細に検討した．さらに，平成20年8月1日に行われた口頭発表後に，第2回学位論文審査委員会を開き，協議の結果，以下のように判定した．

本論文では，近年普及が著しい携帯型IT端末用の文字入力デバイスとして，磁気を利用した装着型の手書き文字入力デバイスを提案している．IT機器に不慣れな高齢者や障害者でも操作しやすいように，特殊なペンやタッチパネル等を使うのではなく，手の平に指で文字を書く動作で入力する新しい方式を考案した．原理は，指先に装着した永久磁石により生じた磁界を，逆の手の手首に装着した磁気センサで検出し，磁石（指先）の位置（軌跡）を求めるものである．磁界は，地磁気の影響を大きく受けるレベルであるため，2個の磁気センサを配し，その出力差により地磁気をキャンセルした．その際，磁石の位置の解析解が得られなくなるため，最急降下法やニュートン法による数値計算法を検討した．また，使用時の磁石の姿勢ずれや書き方によって生じる様々な誤差の影響や，電気ノイズと磁気センサ間距離の関係等についても明らかにした．最終的に，提案する入力デバイスを試作し，手の平に指で書く手書き文字がスムーズに入力できることを示した．

以上のように，本研究は，実用的で有用な新しいユーザインタフェースを開発しており，情報工学，センサ工学の分野に対する貢献度が高いと評価できる．よって，本論文は博士（工学）に値するものと判定する．