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Magnetic Wireless Motion Capturing System and its Application for Jaw Tracking System and 3D Computer Input Device

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We have developed a new tracking system of jaw movement. The system consists of two permanent NdFeB magnets and 32 elements of two-axial fluxgate sensor array. The two magnets are attached to head portion and front tooth. This system does not need any attachments of the head portion or mouth such as clutch or magnetic field sensor except magnets. The proposed system is applicable for five degree of freedom. Position accuracy within 2mm was achieved. We developed a 3D computer input device by using the above mentioned technique.

Key words : tracking system, jaw movement, two magnets, magnetic field sensor

1. Introduction

Tracking of jaw movement is sufficient to characterize the treatment of periodontal disease. Conventional optical methods or mechanical methods have adverse effect due to the presence of metal clutch in the patient's mouth [1]. These clutches disturb the physiology. Conventional magnetic methods have utilized a permanent magnet and magnetic field sensors [2, 3]. The conventional magnetic methods have inherent limitation that the system provides only the position of the point source and the sensors should be fixed to the head. This one point detection is not sufficient to characterize the treatment of jaw movement as a rigid body. A new magnetic tracking system of jaw movement that utilizes five degrees of freedom of the lower jaw is proposed here. There are many tracking systems using permanent magnet and magnetic field sensors [4-7]. The proposed tracking system is based on the magnetic motion capture system with two magnets [8]. The system does not need to fix magnetic field sensors or clutch to the patient's body or mouth. The impact of this result goes beyond the conventional optical and magnetic tracking system of jaw movement.

2. The Proposed Tracking System of Jaw Movement

Fig. 1 shows a photograph of the proposed jaw tracking system. The proposed system has been designed and constructed which utilized two small NdFeB magnets (6 mm × 5 mm × 2.5 mm) on the lower incisor (front tooth) and on the forehead, and 32 elements of commercial two-axial fluxgate sensors (Tokin TMC3000NF). Fig. 2(a) shows the front view and Fig. 2(b) shows the top view of the sensor array. The sensors detect y-direction and z-

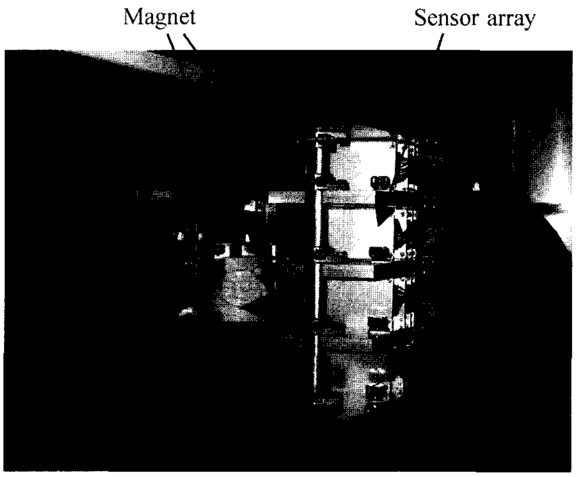

Fig. 1. Photograph of the tracking system and jaw model.

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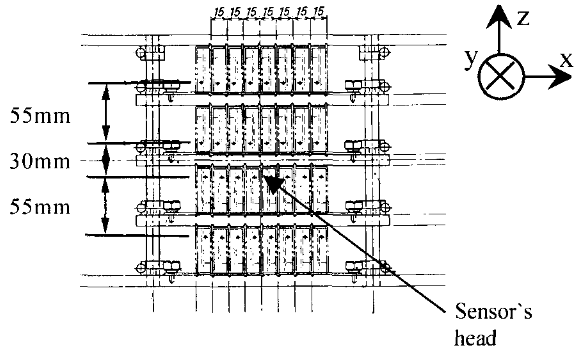
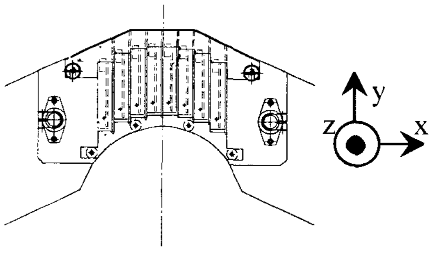


(a) Front view



(b) Top view

Fig. 2. Schematic diagram of sensor array.

direction of magnetic field. The head size of the fluxgate sensor is 13 mm × 13 mm × 2 mm. The internal noise of the sensors was about 0.1 mG in 10 minutes. Fig. 3 shows the tracking process. Firstly, the shape of the jaw as a rigid body is measured by x-ray or another method. Secondly, magnetic field sensors are calibrated. The offset of the sensors output is obtained in background measurement, and the sensor gain is obtained when the magnets are set to the standard point. Thirdly, the position and orientation of the magnets are obtained by the Gauss-Newton method using equation. (1)-(5) [9].

$$S(\vec{p}_1,\vec{p}_2)=\sum_{i=0}^{n}\left(\vec{B}_m^{(i)}-\vec{B}_c^{(i)}(\vec{p}_1,\vec{p}_2)\right)^2=\min \tag{1}$$

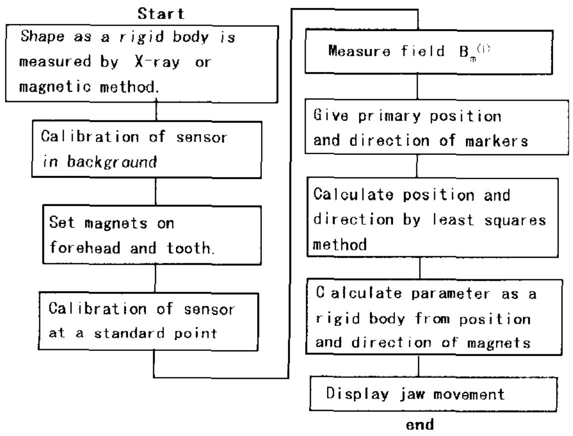


Fig. 3. The process of the tracking of jaw movement.

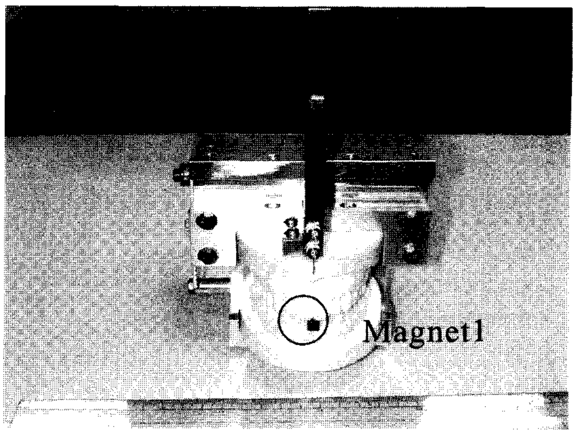


Fig. 4. Jaw model and magnets.

$$\vec{B}_c^{(i)}(\vec{p}_1,\vec{p}_2)=\frac{1}{4\pi\mu_o}\sum_{j=1}^{2}\left(-\frac{\vec{M}_j}{r_{ij}^3}+\frac{3(\vec{M}_j\cdot\vec{r}_{ij})\vec{r}_{ij}}{r_{ij}^5}\right) \tag{2}$$

$$\vec{p}_1=(x_1,y_1,z_1,\theta_1,\phi_1),\ \vec{p}_2=(x_2,y_2,z_2,\theta_2,\phi_2) \tag{3}$$

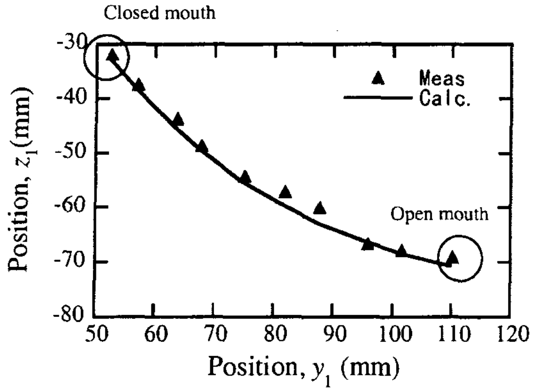
$$\sum_{k=1}^{10}\frac{\partial^2 S}{\partial p_t\partial p_k}\Delta\vec{p}_k=-\frac{\partial S}{\partial p_t},\ (j=1,2,\cdots,10) \tag{4}$$

$$\vec{p}^{(l+1)}=p^{(l)}+\alpha\Delta\vec{p}_k \tag{5}$$

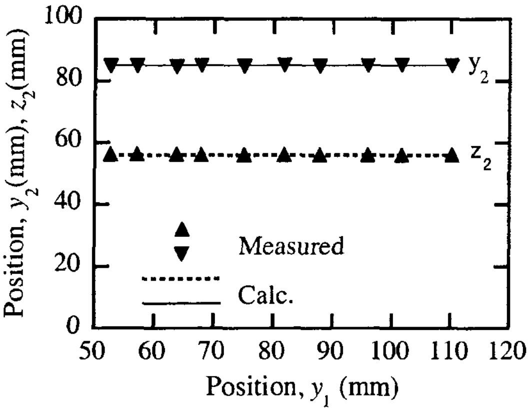
where $S(\vec{p}_1,\vec{p}_2)$ is the least square value, n is the sensor number, B_m is the measured flux density and B_c is the theoretical flux density which is taken into account of dipole field, $\vec{p}_1$ is parameters of magnet1, $\vec{p}_2$ is parameters of magnet2, M is magnetic moment, (x, y, z) is the position of the magnet, θ and ϕ are the orientation angles of the magnet. i means a sensor number, j means the number of magnets, m means the number of parameter. The algorithm is based on the equation of an ideal dipole field, which is expressed as a function of the position and orientation as shown in equation (2).

3. Measured Results

Fig. 4 shows a photograph of the jaw model and magnets. The magnets are attached to the lower incisor (front tooth) and the forehead. The lower magnet can be shifted and the upper magnet is fixed. The motion of the jaw model nearly corresponds to the real motion of the human jaw. Fig. 5(a) shows the profile of the lower magnet (magnet1) in a y-z plane. The measured profile is represented by symbols and the theoretical profile is shown as a rigid line. Measured profile was smooth and the measured data agree well with theoretical profile. The error between measured and theoretical profile was within 2 mm. Fig. 5(b) shows position (y_2, z_2) of the upper



(a) lower magnet (magnet1)



(b) upper magnet (magnet2)

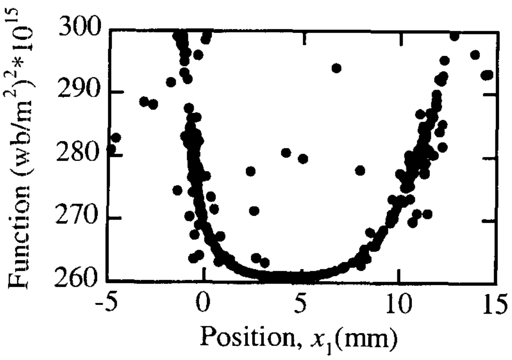
Fig. 5. Profile of the magnets.

magnet (magnet2) when the lower magnets (magnet1) was shifted. The error was within 1 mm. Therefore, we can detect two magnets accurately. The results are acceptable for the tracking of jaw movement.

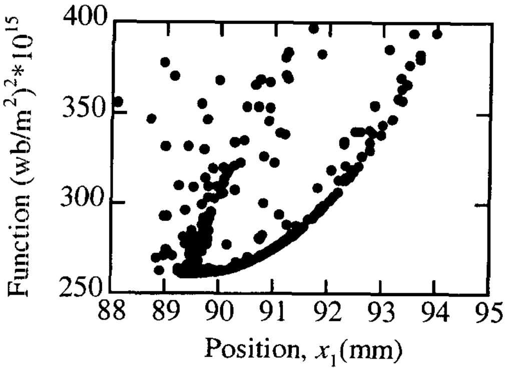
Fig. 6 shows the monitoring of the least square value during the repetition when the random initial parameters were given within 20 mm around the answers. Fig. 6(a) shows *x*-position of the magnet1, (b) *y*-position of the magnet1, (c) *z*-position of the magnet1. In the repetitions the least square value converged on the only answer.

4. 3D Computer Input Device

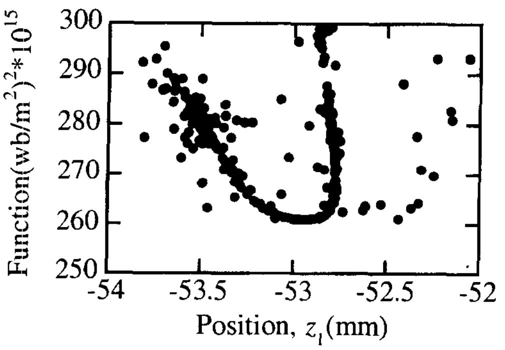
We developed a 3D computer input device which is composed of wireless small marker (permanent magnet) and planar type fluxgate sensors as shown in Fig. 7. The position and orientation of the magnetic maker are obtained by the least square method using measured magnetic field. The magnet is attached to the finger and free from electrical wire. The device is useful to detect hidden objects and provides low cost system. The five degrees of freedom (position and orientation) are detectable.



(a) *x*-position of lower magnet



(b) *y*-position of lower magnet



(c) *z*-position of lower magnet

Fig. 6. The least square value.

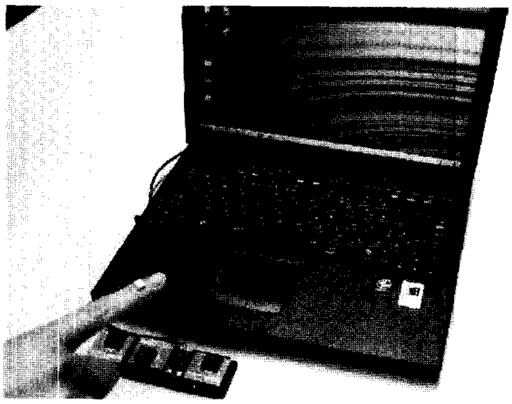


Fig. 7. 3D computer input device.

Conclusion

1. We have developed a new tracking system of jaw movement which consist of two magnets and 32 elements of two axial flugate sensor arrays.

2. Patients don't need to attach a clutch or sensors to their body except magnets using the proposed system.

3. Position accuracy of two magnets was within 2 mm. The accurancy was acceptable for jaw movement.

4. The answer of the least square method was converged on the true answer during the repetition.

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