

# Evaluation of Electromagnetic Measuring Technique of Tip Position of Nasogastric Tube using Evolution Strategy

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**Abstract** — Since a swallowing difficulty patient cannot take a meal by himself, liquid food is poured with the tube (nasogastric tube) that is inserted from a nose to the stomach. It may be inserted into lungs by a mistake. It will become a fatal situation if the nutrition is poured in with incorrect insertion. In this paper, the measuring technique of the position of the tip of the tube by detecting the alternating magnetic field excited from the outside of the human body was proposed. It is shown that the maximum error of positioning is less than 10mm by the experiment in a human body in the clinical test, and then the proposed technique can be applicable in an actual hospital.

## I. INTRODUCTION

A nutrition is poured into the stomach of a patient who has a difficulty in swallowing etc., using the tube (nasogastric tube) made of resin. When the tube is inserted from the hole of a nose to the stomach of the patient by a doctor or a nurse, it may be inserted into lungs by mistake. It will become a fatal situation if the nutrition is poured in with incorrect insertion. In Japan, the accident by this incorrect insertion is caused about 8% every year.

In this paper, the inspection technique of the position of the tip of the tube inside the human body was examined by detecting the alternating magnetic field excited from ten positions on the human body using the 3-axis search coil at the tip of the tube. The position of the tip tube is determined by the evolution strategy [1] using the ac magnetic field detected by the search coil. In addition, the clinical test by a human body is also carried out.

## II. MODEL AND METHOD OF ANALYSIS

### A. Inspection Model

Fig.1 shows the proposed model for detecting the tip position of the inner tube inside the human body. The dimension of the inner tube with 3-axis squared search coil (3x20turns) inserted from the hole of a nose to the stomach is 4mm (diameter) and 1.3m (length). Fig.2 shows the arrangement of the search coil at the tip part of the nasogastric tube. Fig.3 shows the model of ten alternating (ac) exciting coils arranged on the surface of abdomen of the human body. Moreover, the figure illustrates the magnetic moments  $m_k$  ( $k=1$  to 10) that correspond to ten exciting coils. Ten ac exciting coils are constituted in the equilateral triangle whose

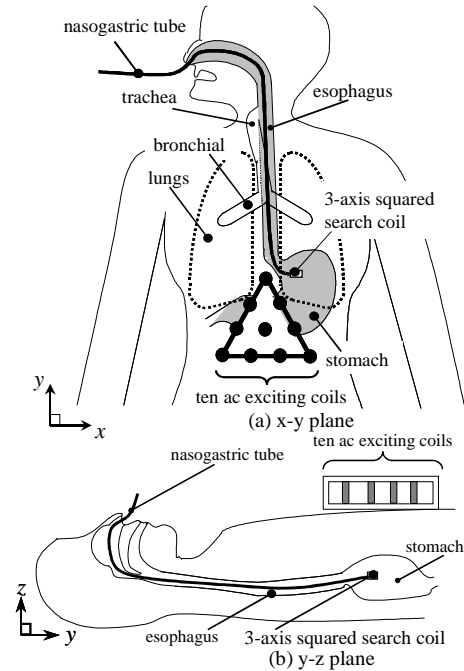


Fig.1. Inspection model for detecting the tip position of the tube inside the human body.

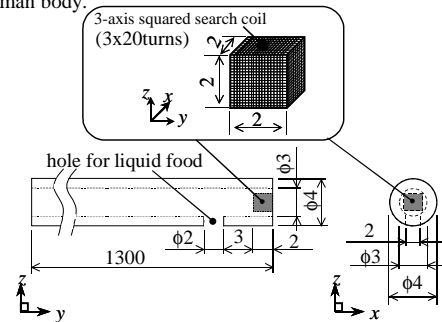


Fig.2. Squared search coil of nasogastric tube tip part.

length of one side is 150mm, and the ac magnetic field of 2.5kHz and 1000 ampere-turns is impressed. The ac-current is impressed in only one exciting coil alternately for 0.1 second, and the ac magnetic field is measured by the 3-axis squared search coil in the inner tube inserted in the inside of the body. Since the distance between the surface of abdomen and the inside of the stomach is about 150mm at the maximum, the maximum inspection domain of minus z-direction from the surface of the abdomen is set as 200mm.

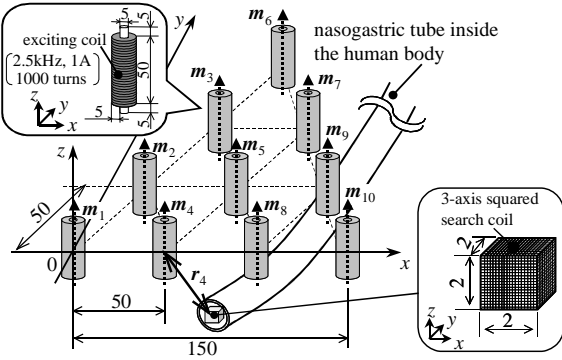


Fig.3. Position of ten ac exciting coils arranged on the surface of abdomen of the human body.

### B. Calculation of Tip Position in Nasogastric Tube

The ac exciting coils are defined as magnetic dipole. The ac magnetic field is produced by the magnetic moment  $\mathbf{m}_k$  of the  $k$ -th coil. A current is fed in only one exciting coil alternately for 0.1 second among ten coils that are set on the human body. The flux density  $\mathbf{B}_k$  produced from the  $k$ -th exciting coil is measured using the 3-axis squared search coil in the tip of the tube inside the human body. The position of the tip is calculated from the flux density measured by the 3-axis search coil using the evolution strategy. The distance  $r_k$  and the magnetic moment  $\mathbf{m}_k$  are chosen as design variables. The initial value of  $r_k$  and  $\mathbf{m}_k$  are set to 50mm and  $0.024\text{Am}^2$ , respectively.

The iteration process of calculation is as follows:

#### 1) Calculation of flux density

The flux density  $\mathbf{B}'_k$  detected by the search coil excited by the  $k$ -th coil is calculated by

$$\mathbf{B}'_k = \frac{\mu_0}{4\pi} \left\{ \frac{3(\mathbf{m}_k \cdot \mathbf{r}_k)\mathbf{r}_k}{r_k^5} - \frac{\mathbf{m}_k}{r_k^3} \right\} \quad (k=1-10) \quad (1)$$

where,  $\mathbf{m}_k$  is the magnetic moment of the  $k$ -th exciting coil.  $r_k$  is the distance between the  $k$ -th exciting coil and the search coil. The calculations are iterated ten times ( $k=1-10$ ) for ten excitation coils.

#### 2) Calculation of objective function

The following objective function  $W$  is calculated:

$$W = \sum_{k=1}^{10} (|\mathbf{B}_k| - |\mathbf{B}'_k|) \quad (2)$$

#### 3) Calculation of distance $r_k$ and magnetic moment $\mathbf{m}_k$

The normal random number  $N(0, \sigma^2)$  ( $\sigma$ : standard deviation) is added to each distance  $r_k$ . The convergence criterion of the standard deviation  $\sigma$  of  $r_k$  and  $\mathbf{m}_k$  are set to 2.25 and 1.125, respectively. The constraint of design variables of  $r_k$  and  $\mathbf{m}_k$  are chosen as  $0 < r_k < 200\text{mm}$ , and  $0 < \mathbf{m}_k < 0.05\text{Am}^2$ , respectively.

Above process is iterated until the final result is obtained.

TABLE I

COMPARISON OF COMPUTED TOMOGRAPHY AND PROPOSED METHOD

case	CT x, y, z (mm)	Proposed method x, y, z (mm)	error $\varepsilon$ (mm)
a	106, 64, -73	101, 56, -71	9.6
b	65, 68, -101	68, 60, -105	9.4
c	89.2, 36.2, -112.7	92.6, 36.1, -113.9	3.6

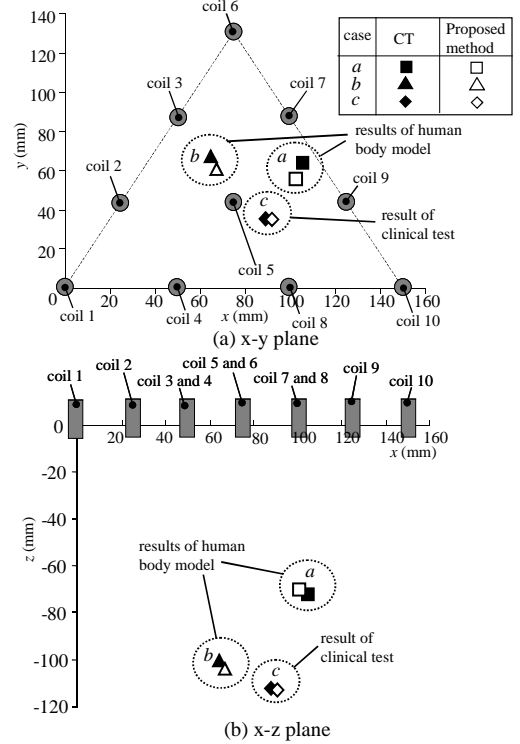


Fig.4. Comparison of results of CT and proposed method (2.5kHz, 1000AT).

## III. RESULTS AND DISCUSSION

The inspection accuracy of the proposed method is examined by comparing with the results of computed tomography (CT) using a human body model and an actual human body. The human body model (MS-1 type) by Kagaku Corporation in Japan was used in the verification experiment. Moreover, a patient of 50 years old was examined in the clinical test.

Fig.4 and Table I show the comparison of results between the results of CT and the proposal inspection method. The position of the exciting coil 1 ( $\mathbf{m}_1$ ) in Figs. 3 is set as the origin of coordinates. The error  $\varepsilon$  (mm) is defined as the distance between the measured position by CT and the estimated position by the proposal inspection method. The black signs in the figure show the measured positions of the search coil by CT, and the white signs show the estimated positions by the proposal inspection method. The positions of cases a and b are the evaluation results by the human body model. The case c is the results by a human in the clinical test. The figure and table denote that the measured positions by CT and the estimated position of the search coil are in good agreement with less than 10mm error. Especially, the error  $\varepsilon$  of the case c is 3.6mm. In an actual hospital, since the maximum error  $\varepsilon$  of an allowable inspection position is about 10mm, the proposed inspection technique is applicable.

## IV. REFERENCE

- [1] T.Bäck, "Evolutionary Algorithms in Theory and Practice", Oxford University Press, 1996.