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A BASIC RESEARCH FOR DISCRIMINATION OF LIVING BODY TISSUES USING TACTILE SENSOR

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Abstract – It is dispensable to develop the discriminating method of the human body tissues for the automation of the operation using robots. The piezoelectric elements are used as the sensor to measure the qualities of the living body. The discrimination for various meats as the living body is tried using the developed tactile sensor. It is shown that the discrimination among the living tissues is possible using the proposed tactile sensor.

Keywords: Tactile sensor, Discrimination of tissues, Piezoelectric element

1. INTRODUCTION

The palpations are used for the diagnosis of liver cirrhosis, peritonitis, mammary cancer, thyroid cancer, etc., in the medical institutions such as the hospital. In the operation, the doctor carries out the treatment by palpating the organs of the patient. The data got from the palpations by the doctor is for discerning the situation of the patient lesion. However, all doctors not always carry out the accurate diagnosis. The accurate diagnosis by the doctor palpation reflects the experience of the doctor until now. The utilization of the sensors on the palpation is considered for making the accurate diagnosis without relating to the experience of the doctor. The palpation information is quantitatively obtained using the sensors as a method for making the accurate diagnosis. The studies of the sensors for the human five senses are carries out widely. Especially, the development of the sensors that is related to the visual image and the auditory sense is actively carried out. However, the researches on the tactile sense are carried out but they are not active. As the researches of the tactile sense sensors, there are researches of the hardware configuration that constitutes the sensor and researches of the algorithm using the sensors. In the surgery, the operation using the endoscope becomes popular in order to reduce the load to the human body. The operation is called a non-invasive operation. In addition to the non-invasive operation, the automatically operation is desired. The trials for automatically operation are carried out using robot and image sensor. The largest problem in the surgery robots is that the robots don't have the tactile sense sensors. In this study, the tactile sensor composed the piezoelectric devices into the ball-point pen is realized and the algorithm using the Euclid's distance is proposed. The time series data from the tactile sensor is changed into the frequency spectrum using MEM (Maximum Entropy Method). The discrimination of the hardness on the bio-tissue becomes possible by EED (Evaluation by Euclid Distance) method that improved the MT(Mahalanobis-Taguchi) method. In the experiments, the meats are distinguished. The meats of chicken, pig, and cattle are used as the living bio-tissues. The basic research is tried for the discrimination of the visceral tissues by the tactile sensor when the robot is made to possess the tactile sensor.

2. STRUCTURE OF SENSOR

2.1 Structure

The piezoelectric devices of zircon lead titanate are included in the ball-point pen shaft. The constructed tactile sensor is shown in Fig. 1. Two piezoelectric devices are used. One makes the ball-point pen shaft resonate, and other one is made to be the element for the vibration detection. The cylindrical PZT is fixed in the shaft of the ball-point pen. The forced vibration is induced by this PZT. One more PZT is fixed outside the cylindrical PZT. The vibration mode is detected with this PZT. The change of the resonant frequency is detected with the phase shift circuit, when the ball-point pen touches the measuring object. The frequency change is proportional to the hardness and softness of the measuring object.

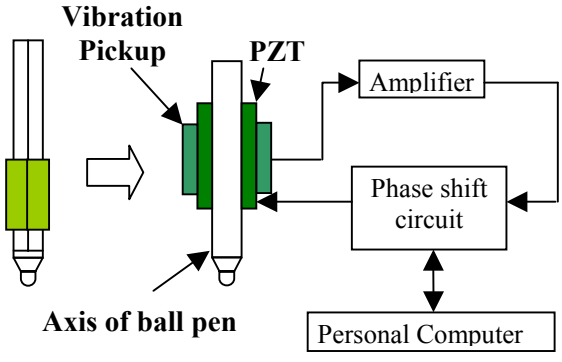

Fig.1. Structure of tactile sensor

2.2 Measuring principle

The resonant frequency is changed when the sensor contacts the measuring object from the resonant frequency in the condition that the sensor has not contacted the object, as it is shown in Fig. 2.

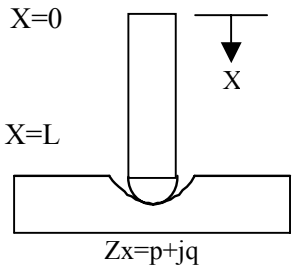

Fig.2. Model of measuring

The change of the resonant frequency is shown in the next equation.

$$\Delta f = -\frac{C_r q_x}{2n\pi L Z_r} \qquad (1)$$

Where, Z_r is acoustic impedance of the rod, q_x is reactance of Z_x, n is vibrating number and L is the length of the rod. The time series data of the hardness of the measuring object is obtained by moving the tip of the ball-pen along the measuring object. The frequency spectrum of the time series data of the hardness is obtained using Maximum Entropy Method (MEM). The Euclid standard space is made on the basis of the frequency spectrum data and the measuring object can be discriminated using EED method.

3. EED (EVALUATION BY EUCLID DISTANCE)

3.1 Euclid distance

MT method is a method for judging where the data belongs to by the distance from the standard origin. The data of the homogeneous group is settled as the standard space and the distance of the unknown data from the origin is calculated and whether the unknown data belongs to the homogeneous group or not is determined. It is the technique that carries out one scale of the distance for the data of multidimensional information and the discrimination among the data by the distance. If there is correlation among the collecting data, the distance becomes a Mahalanobis distance and if there is not correlation among the data, the distance becomes a Euclid distance. In this study, the large virtual data arises based on the collected data using the orthogonal array and the calculated distance becomes Euclid distance. Fig. 3. shows the outlook of the EED method.

3.2 Calculating Euclid distance

The Euclid standard space and the Euclid distance are calculated from the next equations. The data is standardized using the mean value m and the standard deviation σ of the collected data as shown in equation (2).

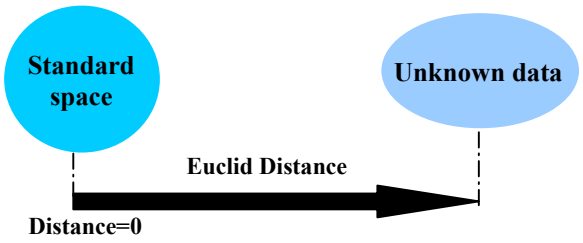

Fig. 3. Euclid distance

$$x_{ij} = \frac{X_{ij} - m_i}{\sigma_i} \qquad (2)$$

The correlation matrix R is calculated.

$$R = \begin{pmatrix} 1 & r_{12} & \cdots & r_{1k} \\ r_{21} & 1 & \cdots & r_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ r_{k1} & r_{k2} & \cdots & 1 \end{pmatrix} \qquad (3)$$

Where,

$$r_{ij} = \frac{1}{n}(x_{i1}x_{j1} + x_{i2}x_{j2} + \cdots + x_{in}x_{jn}) \qquad (4)$$

Next, the inverse matrix of the correlation matrix is derived by next equation.

$$A = R^{-1} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1k} \\ a_{21} & a_{22} & \cdots & a_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ a_{k1} & a_{k2} & \cdots & a_{kk} \end{pmatrix} \qquad (5)$$

Euclid distance is calculated using the next equation.

$$D^2 = \frac{1}{k}\sum_{i=1}^{k}\sum_{j=1}^{k} a_{ij}x_i x_j \qquad (6)$$

4. EXPERIMENT

4.1 Conditions of experiment

The meats of the type and position of the domestic animal as the biotissues are experimented as the examples of the experiment. The used meats are shown in Table.1.

Table. 1. Meats used in the experiment

Beef	Pork	Chicken
Thigh	Thigh	Thigh
Lever	Lever	Lever
Chuck roll	Loin	White meat
Tongue	Tongue	Breast
Tender loin	Tender loin	Gizzard
Short plate	Spareribs	———
Strip loin	Heart	———

The procedures of the experiment are shown as follows:

(1) The figure "2" character is written on the meat by the sensor and the time series-data is obtained.
(2) Using the MEM, the time series data is changed into the frequency spectrum.
(3) The frequency spectrum is divided into 255 equally. Using L_{256} orthogonal array, 256 virtual data arise from the collected data and the orthogonal array.
(4) The Euclid standard space is constituted used the virtual data from the orthogonal array.
(5) The Euclid space is constituted using the virtual data of the orthogonal array data.
(6) Euclid distances are calculated for the various meats.
(7) The type and position of the meats are distinguished of the Euclid distance.

The various meats like the beef, pork, chicken are treated and the thigh, lever, chuck roll, tongue, tender loin, short plate, strip loin, loin, spareribs, heart, white meat, breast and gizzard are used for the experimental objects.

4.2 Experimental results

As the examples of the experimental results, Fig.4 shows the time series data of the contact pressure for the thigh of the beef. Fig. 5 shows the frequency spectrum of the above time series data using MEM.

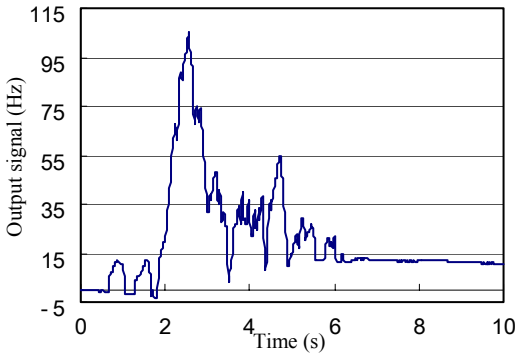

Fig.4. Time series data of beef thigh

The discrimination result of the beef is shown in Fig.6. The standard space is constructed of the thigh meat. Fig.7 shows the case of the pork and Fig.8 shows the case of the chicken. In the both cases, the standard space is constructed of the each thigh meat.

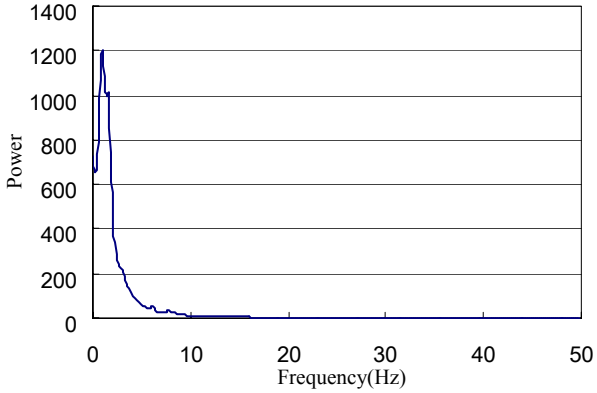

Fig.5. Frequency spectrum of beef thigh

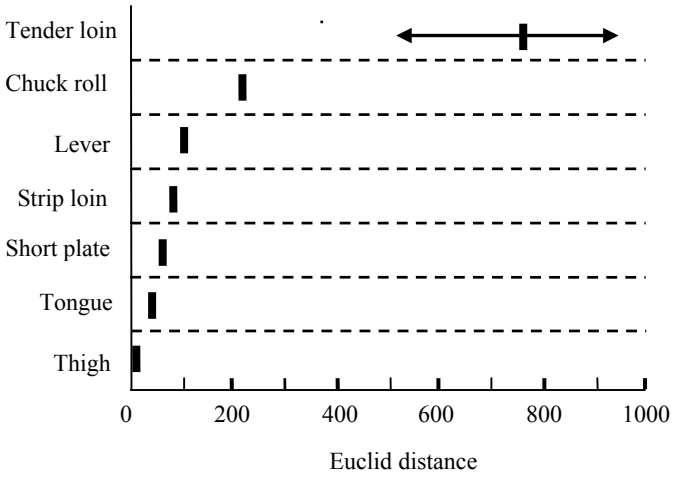

Fig.6. Discrimination result of beef

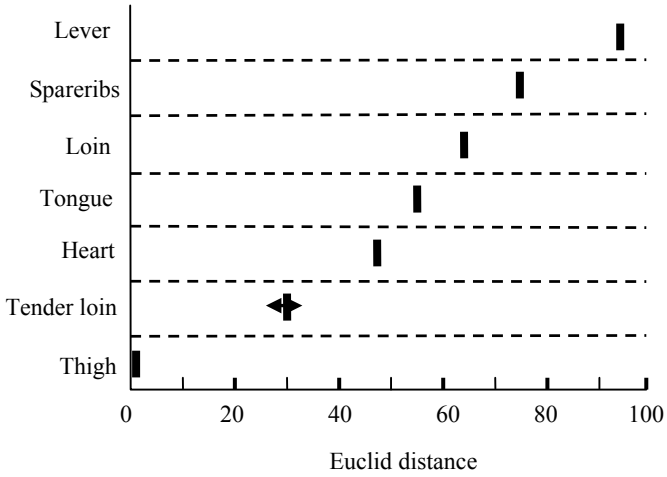

Fig.7. Discrimination result of pork

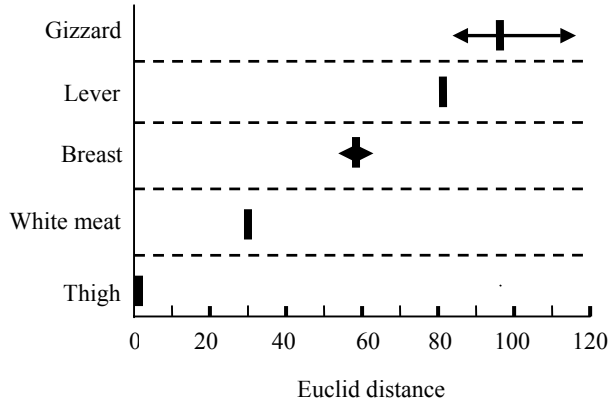

Fig.8. Discrimination result of chicken

As shown in Fig.6-Fig.8, the discrimination of the position of the meat is possible by the Euclid distance. The discrimination results of the lever and the thigh are shown in Fig.9 and Fig.10. It is shown that the pork meat and chicken meat can discriminate from the beef meat in making the beef to be the standard space.

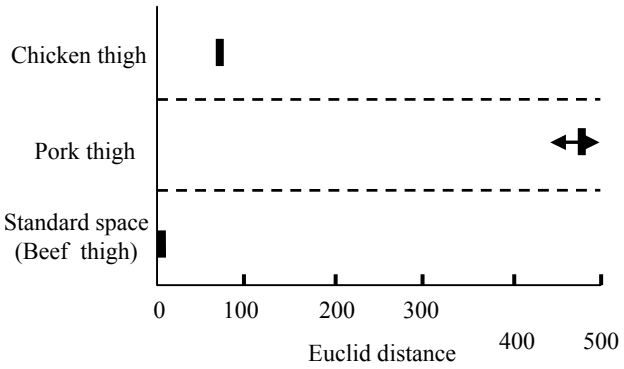

Fig.9. Comparison of thigh meats

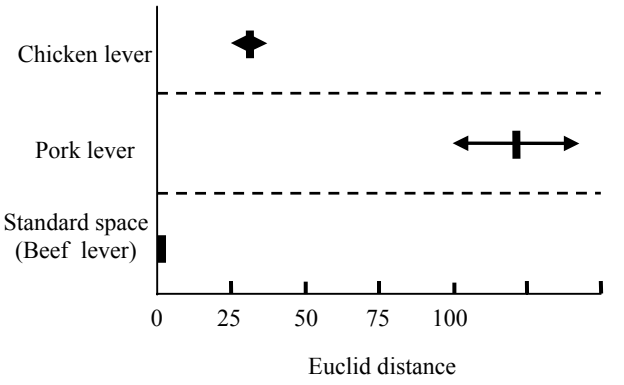

Fig.10. Comparison of lever

From the experimental results shown in the above, it is shown that the discrimination of the biotissues is possible using the tactile sensor that built in the piezoelectric devices into the ball-point pen and using the discrimination method by the Euclid distance.

5. CONCLUSIONS

The method for the ultimate surgery is to automatically execute the operation by the robots with the sensors. The operation is carried out with the discrimination of the viscera tissues by the sensors. The discrimination experiments for various meats were carried out and the effectiveness of the proposed device and method was shown. The conclusions in this study are as follows:

(1) Using the tactile sensor of ball-point pen type and the EED (Evaluation by Euclid Distance) method, the discrimination for living body tissues is possible.
(2) It is possible to carry out the high-precise discrimination by the frequency spectrum using the MEM (Maximum Entropy Method) analysis for the time series data from the sensor as the input data of the standard space.
(3) It is shown that the discrimination accuracy can be heightened using the virtual data group from the orthogonal array.

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