A Mono-Material Tactile Sensor with Multi-Sensing Properties

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Abstract

To realize artificial device with sensing ability of the human skin, a mono-material tactile sensor with three sensing functions made of some elastic thin electro-conductive rubber sheet with eight latticed patch elements is proposed.

This trial sensor provides the information of three kinds of model material characteristics such as thermal property, hardness property and the surface situation of materials by setting up three kinds of surface models as test materials.

It can be finally expected to estimate unknown model materials by analyzing the data of the sensor.

1. Introduction

For a long time, various tactile sensors including new sensing techniques called the intellectualization of sensors have been investigated by many research groups[1],[2].

However, even these so-called intelligent tactile sensors are not free from the conception of the sensor which possesses a single objective.

We propose here a mono-material tactile sensor with three sensing functions to realize the sensing of the human skin artificially. The human skin, especially, the palm of a hand has many tactile functions. One of the most important functions in the palm is to discriminate materials.

For recognizing material properties, the pressure sensitivity and the thermal sensitivity are main characteristics in the sensing abilities of the palm.

In this study, some elastic thin electro-conductive rubber sheet is used to realize artificial device with sensing ability of the human skin. The rubber sheet has been usually used as a touch sensor which aims at the recognition of the pressure of test materials. The rubber sheet is, however, sensitive not only for pressure but also for temperature. Therefore, to realize a tactile sensing material imitating the human skin, we tried to use the characteristics of rubber sheet having pressure sensitivity and thermal sensitivity.

To recognize material properties, furthermore, some touch feeling to the surface of material is experientially known as one of the most important sensing abilities in the human skin.

In this study, an additional function of a property such as a sensing ability in the human skin that distinguishes the difference of feeling on the surface of materials is prepared by constructing the proposed tactile sensor with eight latticed patch rubber elements and by setting up three kinds of surface models as test materials.

By the trial mono-material tactile sensor with multi-sensing properties using elastic thin electro-conductive sheet rubber elements, therefore, the information of three kinds of model material characteristics such as thermal property, hardness property and the surface situation of materials can be obtained. As a result, it can be finally expected to estimate unknown model materials by analyzing these data.

2. An Idea of Mono-Material Tactile Sensor with Multi-Sensing Properties and Surface Models of Test Materials

Fig. 1 shows an idea how to simulate the human skin to pressure-sensitive sensors. This idea indicates that a small part of the human skin is regarded as a group of a large number of tactile sensors, and one of these tactile sensors is regarded as a large number of groups consisted of several kinds of pressure-sensitive sensors.

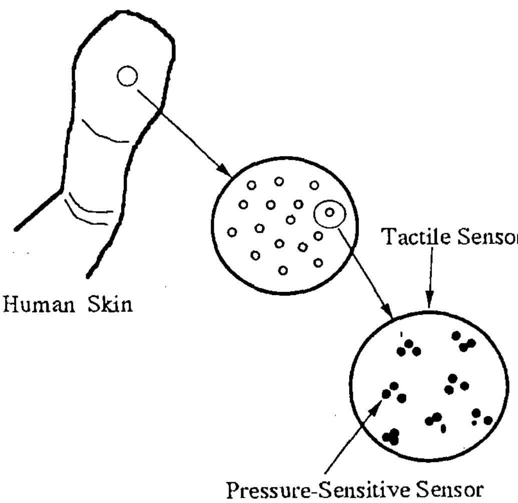


Fig.1 Comparison of human skin and pressure-sensitive sensors

By simplifying the surface situation of materials and by constructing a single tactile sensor with some small patched rubbers, the different reactions of sensor to various surfaces of test materials can be realized.

Fig. 2 shows three simplified examples of various surface situations of materials. The dimension of contact area between the human skin and the material seems to be an important factor to distinguish material properties. Three kinds of surfaces of typical

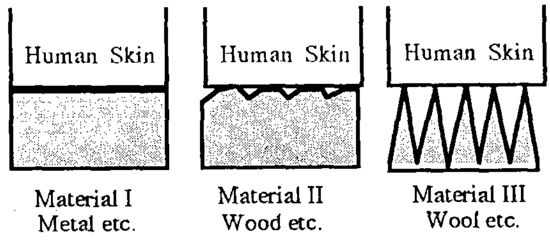


Fig.2 Three simplified examples of various surface situations of materials

materials such as metals, wood and wool are adopted as surface models. Fig. 3 shows the design of trial tactile sensor that is made of elastic thin electro-conductive rubber sheets of 0.5 mm in depth. This sensor is constructed with eight patched rubber elements that are latticed on the squared acrylic resin substrate of 7 cm x 7 cm except a central part for monitoring the temperature.

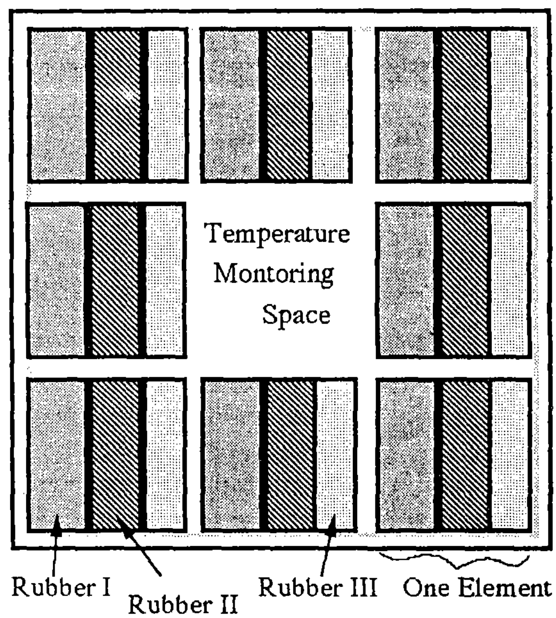


Fig.3 Design of trial tactile sensor made of elastic thin electro-conductive rubber sheets with eight patched elements

Furthermore, each of eight patched rubber elements in the sensor is consisted of three parts as shown in Fig. 3. These three parts have different sensing characteristics each other. The parts of rubber-I have the most sensitive resistivity for pressure change and the parts of rubber-III have the least.

Fig. 4 shows a cross section of a part of the sensor. Each rubber with one of a pair of metal electrodes under the rubber is put on the substrate of acrylic resin and the other electrode on the rubbers is used in common.

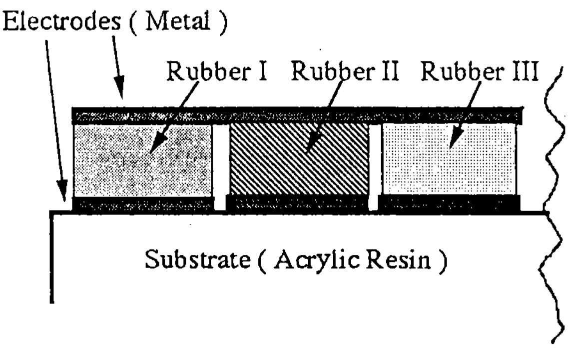


Fig.4 A cross section of a part of the sensor

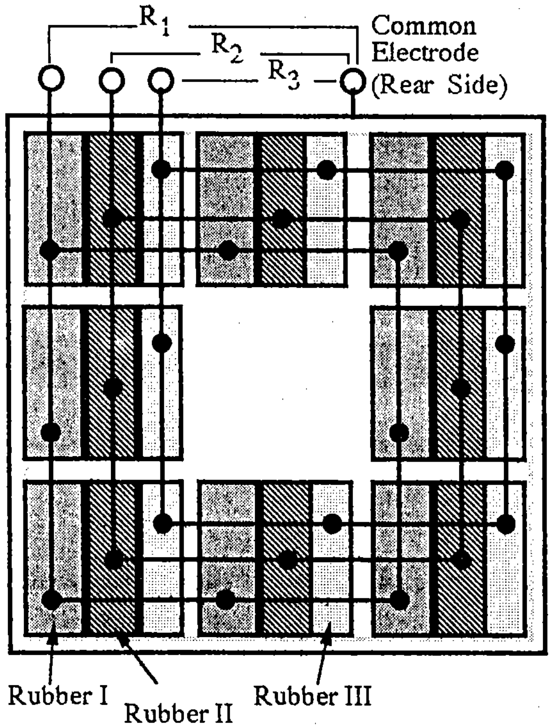


Fig.5 Electrical connection of electrodes with rubber elements

When a test material is put on the upper electrode, the resistance of rubber between two electrodes is obtained according to the situations such as pressure, temperature and surface patterns.

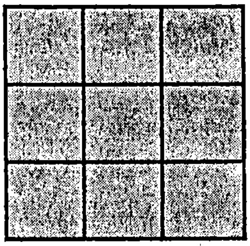
As shown in Fig. 5, each electrodes attached to the rear side of these three parts in the patched rubber element is electrically connected in parallel with all the same part of eight elements.

Therefore, only three different electrical output signals of the sensor can be obtained as resistance values because of the electrical combination of these elements. This configuration of the sensor can be expected to realize some characteristics of the human skin that is simply diagrammed in Fig. 1.

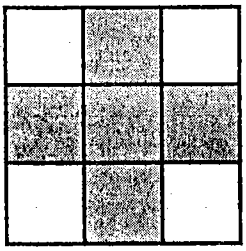
On the other hand, Fig. 6 shows that three simplified examples of various surface situations of materials shown in Fig. 2 is also constructed as three surface pattern models in our study. According to the dimension of contact area between the sensor and the material, the surface pattern model - I in Fig. 6 represents the material - I such as metals in Fig. 2, and the model - II or II' shows the material-II such as wood, and the model - III or III' also expresses the material-III such as wool.

By putting each of these pattern models on the trial tactile sensor with eight patched rubber elements, the differences of the surface of test materials can be recognized through the result of experiments.

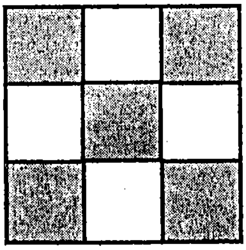
Some characteristics of the rubber, such as hysteresis and creep effects may have an unfavorable influence upon the measurement. In this study, therefore, discrete loads using several kinds of weights are adopted, and as a result, notwithstanding the hysteresis and the creep effects of rubber, the discriminated results are obtained.



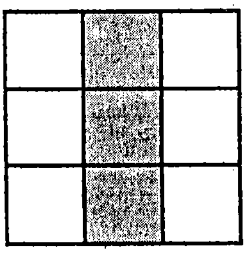
Surface Pattern Model - I



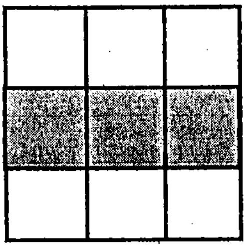
Surface Pattern Model -II



Surface Pattern Model -II'



Surface Pattern Model -III



Surface Pattern Model -III'

Fig.6 Three surface pattern models of three simplified examples of various surface situations of materials

3. Basic Characteristics of Elastic Thin Electro-Conductive Rubber Sheets

The elastic thin electro-conductive rubber sheet adopted to our trial tactile sensor is now mainly used as pressure-sensitive devices in several two-dimensional pressure image indication systems such as movements of the sole, the palm and the hips on a chair. This rubber sheet which has been developed by Yokohama-Gum Co., Ltd. and has been on sale by Yokohama Image System Co., Ltd. is composed of silicon gum and conductive powder.

Fig. 7 shows the resistance changes of the rubber sheet as a function of temperature in

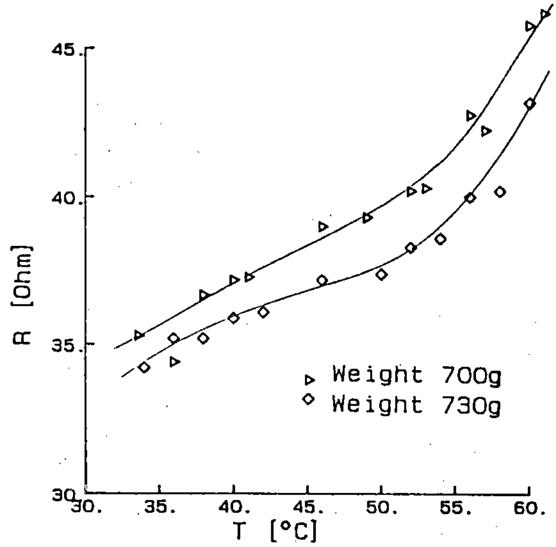


Fig.7 Resistance changes of the rubber sheet as a function of temperature in two kinds of constant weights

two kinds of constant weights, 700 grams and 730 grams. This result indicates a great influence of temperature for the characteristics of rubber sheet.

Fig. 8 shows the resistivity change of three kinds of different pressure-sensitive rubber sheets as a function of pressure in constant temperature of 24 degree Cels..

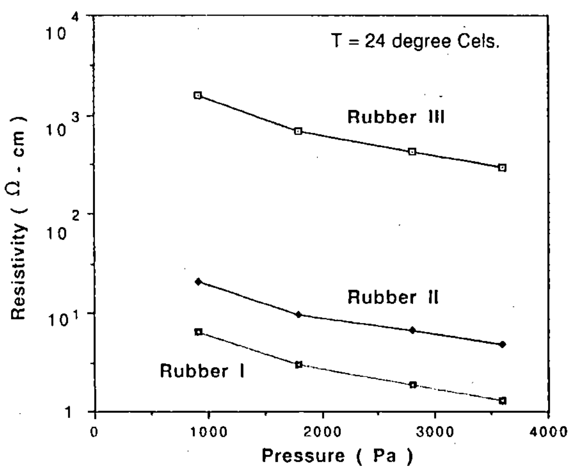


Fig.8 Resistivity change of three kinds of different pressure-sensitive rubber sheets as a function of pressure in constant temperature of 24 degree Cels.

From these two figures, we understand that an output signal expressed by a resistance value of the rubber sheet is obtained as the result of combinations of weight and temperature.

The characteristics of rubber are, in general, not good concerning to the reproducibility because of hysteresis and creep effects.

In this study, therefore, by changing loads on the rubber sheet not continuously but discretely, resistance values of rubber sheets related to the pressure can be measured separately within the limits of an accidental error despite the hysteresis and the creep effects of rubber. Such a measurement method is sufficient to recognize the hardness of test materials.

4. Experimental Results of the Trial Tactile Sensor depending on Three Kinds of Surface Patterns in the Model Material

Fig. 9 shows the diagram of measurement system. Various loads having three kinds of different surface patterns are put on the sensor. Output signals of the sensor depending on the pressure, the temperature and the surface patterns are measured by a digital multimeter. These resistance values are sent and filed to a personal computer as a data-base.

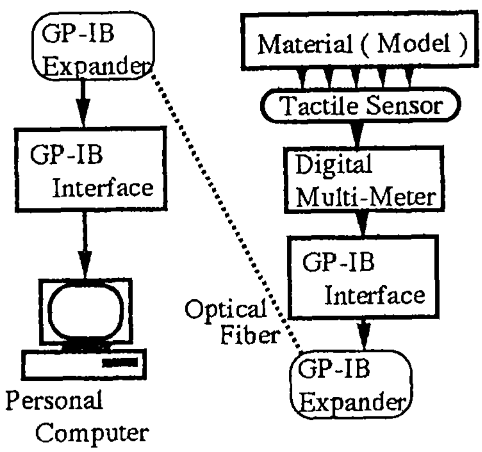


Fig.9 Diagram of measurement system

The output signals are exchanged on the way to optical signals through optical fibers and GP-IB expanders not to make the measurement system influence the noise of computer.

Fig. 10 shows the resistance changes of rubber II part in the trial tactile sensor consisted of three kinds of different pressure-sensitive rubber sheets as functions of weight, temperature and three kinds of surface patterns of model materials. Average values of fifty times of measurements are plotted in each point. Each accidental error is about 10 %.

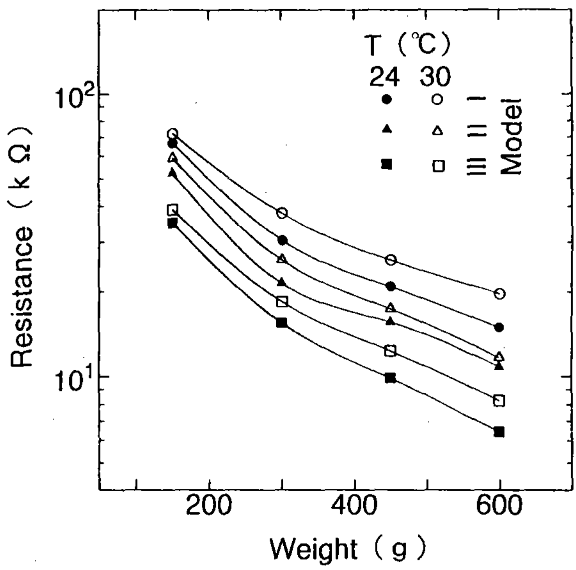


Fig.10 Resistance changes of rubber II part in the trial tactile sensor consisted of three kinds of different pressure-sensitive rubber sheets as functions of weight, temperature and three kinds of surface patterns of model materials

5. Discussion

Each resistance value in three output terminals of the trial sensor results from the combination of three conditions such as pressure, temperature and surface situation of test material. One resistance value of each output includes many combinations of values in three conditions. Therefore, one fixed combination can not be pointed out by one output resistance value.

When one common combinated situation of pressure, temperature and surface in three groups of the many possible combinations introducd from each resistance value of three output terminals is found, this common combination can be estimated as the most probable combination of these three conditions.

It is expected in future that unknown materials are estimated by obtaining the thermal conductivity, the hardness and the surface situation of test material through the above-mentioned measurement technique. If this trial sensor can be microminiaturized, a figure size tactile chip device assembled with a large number of micro sensors will be put into practical use in place of human skin for recognizing materials.

6. Conclusion

To realize an artificial sensing device of the human skin, the idea concerning to a mono-material tactile sensor with three sensing functions was proposed. This trial tactile sensor is made of elastic thin electro-conductive rubber sheet which is sensitive pressure and temperature.

Furthermore, for discriminating the difference of the surface situation of materials, the construction of the proposed tactile sensor with eight latticed patch rubber elements and the representation of test materials by three kinds of surface models were prepared.

In this paper, the characteristics of temperature and of pressure in the elastic thin electro-conductive rubber sheet, and also the characteristics of trial tactile sensor putting on three kinds of surface models of test materials were described.

By these results, it is expected that the information of three kinds of characteristics such as thermal property, hardness property and the surface situation of model materials can be obtained, and then the estimation of unknown material can be realized in future by manufacturing a micro device of the proposed tactile sensor.

References

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