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A new sensing method using contact voltage for material discrimination

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ABSTRACT

This paper proposes a new tactile sensing method for material discrimination. The proposed method is based on the fact that the voltage induced by contact between the proposed tactile sensor and the material (contact voltage) is different according to the material in question. This makes it possible to discriminate materials by using the contact voltage waveform. In the experiment, four kinds of materials: aluminium, acrylic resin, urethan gel, and silicone sponge were prepared and the ability to discriminate the different materials was demonstrated using the contact voltage characteristic and the usefulness of the proposed sensor was discussed.

1. Introduction

Human beings have several tactile sensitive functions. They discriminate the qualities of a material such as its hardness, viscosity, shape, and surface condition by touching or contacting the object. Numerous projects have investigated tactile sensors that imitate the hand of the human being, especially, the skin sensitivity of the finger using optical sensors including CCDs, conductive elastomer, strain gages and so on [1]. A finger-shaped tactile sensor based on an optical sensor including a CCD [2–4], a fingered tactile sensor using pressure conductive rubber [5,6], a cylindrical touch sensor which measures contact strain [7], a tactile sensor based on an acoustic sensor for shape discrimination [8], and a thermal sensor of the gripped object [9] have all been researched. Other reports have proposed a tactile sensor based on a vision sensor with a strain gage for a stable grasp and sensing the slippage [10], a tactile sensor for detecting contact force and hardness based on a diaphragm, a piezo-resistive displacement sensor, and a chamber for pneumatic actuation [11], and a tactile sensor for contact force and slip based on polyvinylidene fluoride (PVDF) and a pressure variable resistor [12].

The purpose of our research is to develop a tactile sensor of the robot hand. To achieve this, we propose a new tactile sensor which detects the qualities of a material such as the electrical properties, ultrasonic properties, and mechanical properties including its surface condition. Fig. 1 shows the proposed sensor based on the micron-scale piezoelectric ceramic transducer for the robot tactile sensor. The proposed sensor measures the ultrasonic properties of the object with piezoelectric ceramic transducers in the contact and also measures the electrical properties by using a pair of piezoelectric ceramic surface electrodes in the non-contact or the contact [13]. Therefore, the electrical and ultrasonic properties are simultaneously measured by the same sensor. The quality of material is estimated from their measured values. Actually, we have already not only discriminated the four kinds of materials but also detected the thickness and the hardness by using a pair of the large scale piezoelectric ceramics as the measurement of a part of the proposed tactile sensor as shown in Fig. 1 [14].

This paper presents an addition to the previously proposed ultrasonic and electrical sensing method. This new sensing method uses the voltage which is induced by the contact between the sensor and the material (the contact voltage) because it would be caused by material properties such as the hardness, tensile strength, electrostatic property and the surface condition. Accordingly, it is possible to discriminate various materials by extracting the characteristics of the contact voltage waveform. Thus, we can obtain information about several characteristics simultaneously by using the contact voltage together with measurements of the electrical and ultrasonic properties. In our experiment, the discrimination of four materials – aluminium, acrylic, urethan gel and silicone sponge – was demonstrated using the contact voltage obtained by a large-scale piezoelectric ceramic transducer as the first trial. In addition, the usefulness of the proposed sensor was discussed.

2. Measurement principle

Fig. 2 is a schematic diagram of the proposed method for measuring the electrical and ultrasonic properties and contact voltage

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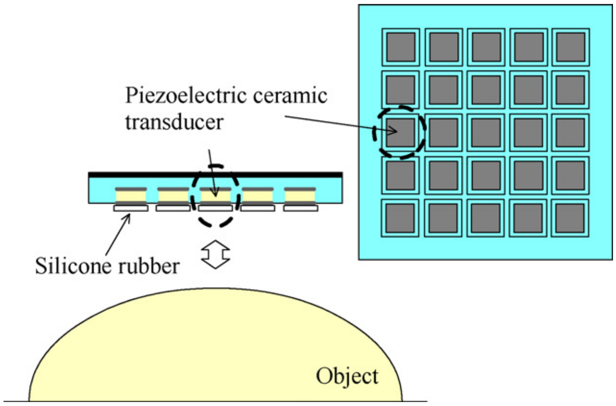

Fig. 1. Schematic diagram of proposed touch sensor for material discrimination.

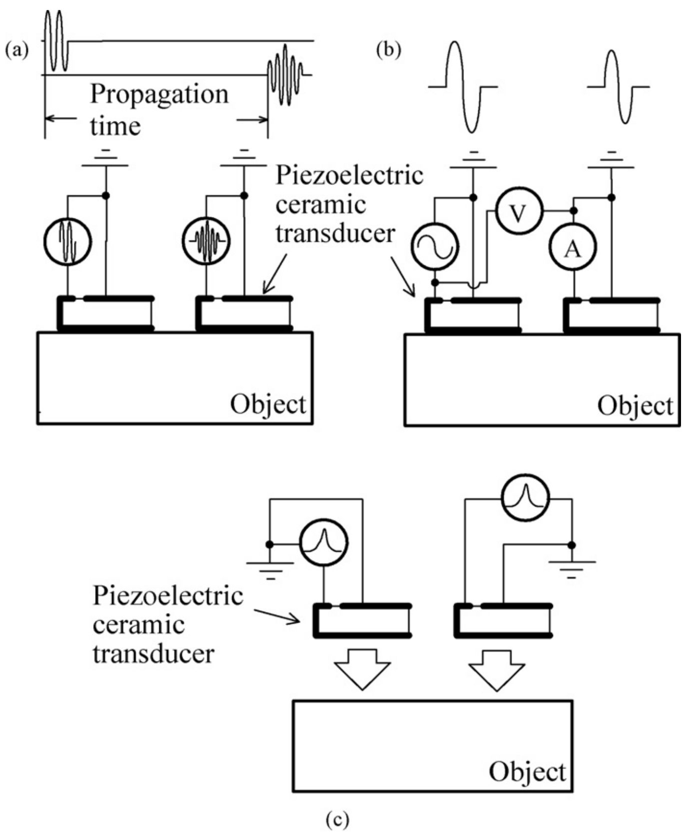

Fig. 2. Proposed sensing method: measurements of (a) ultrasonic property, (b) electrical property and (c) contact voltage.

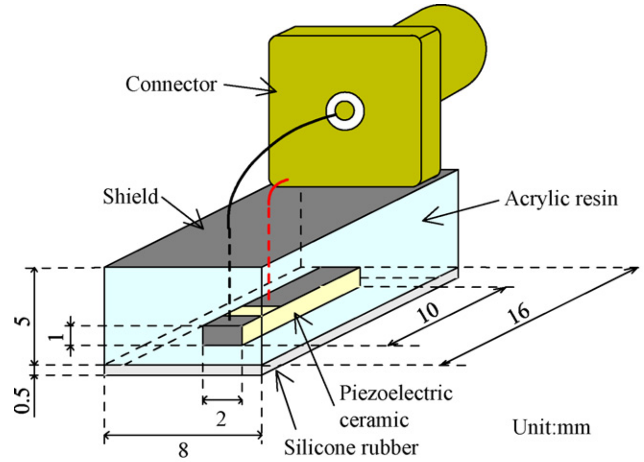

Fig. 3. Schematic diagram of proposed touch sensor.

using a pair of piezoelectric ceramic transducers. The ultrasonic property is measured by the transducers, one of which is used as the transmitter and the other as the receiver. At the same time, the electrical property is measured by the surface electrodes of each transducer. In addition, the voltage induced by contacting the material (the contact voltage) is obtained. It is possible to obtain information about the material by extracting the waveform of the contact voltage because the waveform would be influenced by material properties such as the hardness, tensile strength, electrostatic property and the surface condition. In this way, one sensor can obtain information about several characteristics of the material by simultaneously measuring the contact voltage together with the electrical and ultrasonic properties.

3. Experimental method

Fig. 3 is a schematic diagram of the proposed sensor for measuring the contact voltage. A piezoelectric ceramic transducer (Fuji Ceramics Corp. C6, 10 mm × 2 mm × 1 mm) with a 2 MHz resonance frequency was mounted on an acrylic plate (16 mm × 8 mm × 5 mm). A silicone rubber sheet with 0.5 mm thickness was also pasted on the surface of the sensor to stabilize contact conditions between the proposed sensor and the measurement material. The proposed sensor was fixed to the wood plate (10 mm × 20 mm × 30 mm) and attached to the head of a robot arm (DENSO VS-6354DM) as shown in Fig. 4.

Fig. 5 shows the measurement system for contact voltage. The proposed sensor was touched the measurement material with a constant contact force and speed by controlling the robot arm. The measurement material was fixed on the aluminium plate with

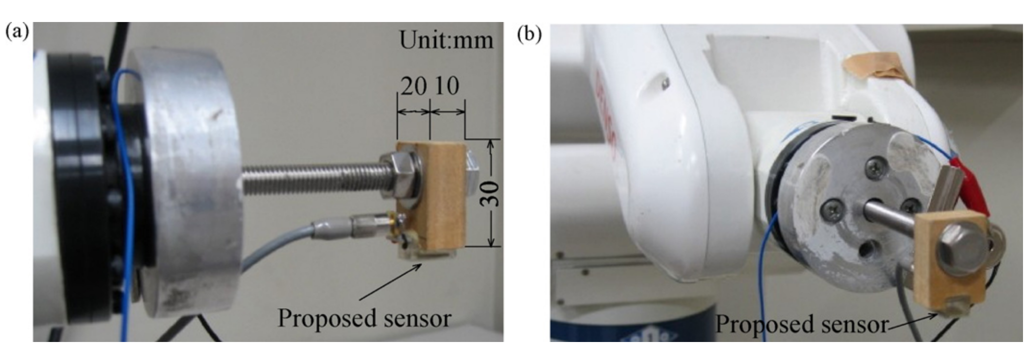

Fig. 4. The proposed sensor attached to the robot arm: (a) side view and (b) top view.