様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

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研究課題名（和文）Small sized force/torque sensors for robotic arms and hands

研究課題名（英文）Small sized force/torque sensors for robotic arms and hands

研究代表者

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研究成果の概要（和文）：本研究では容量型かつホール効果計測に基づく触覚センサーを開発し、ロボットハンドに実装した。主要な新規性としては、小型でソフトな形状の３力軸センサー（X.Y.X軸）を可能した点である。加えて、容量型６軸力トルクセンサーが実装されている。また必要最低限のワイヤですべてのセンサーが統合できる。さらに、巧みなハンド操作を目指す研究も実施した。

研究成果の概要（英文）：We developed tactile sensors based on capacitive and Hall effect sensing, and implemented them in robot hands. The main novelty is that the skin sensors enable 3-axis force sensing (x,y,z force) in a small and soft form factor. Moreover, capacitive 6-axis force-torque sensors were implemented. All sensors require a minimum number of wires for ease of integration. Furthermore, we performed research on in-hand manipulation.

研究分野：　Robotics

キーワード：　Tactile Sensor　Force Sensor

１．研究開始当初の背景

Measuring the contact forces is crucial to ensure a safe and robust interaction of a robot with unknown environments. In humanoid robots the available space for sensors is limited. Not only the space for the transducer, but also the space for the readout circuit and the wires needs to be taken into account.

２．研究の目的

The goal of this project is to develop a tactile robot hand for safe and dexterous human-robot interaction. Existing sensors are too big, need many wires, or cannot measure the force vector. We will develop novel 6-axis force/torque (F/T) sensors for fingertips as well as distributed 3-axis force sensors. The sensors will be integrated into a robotic hand. Common problems such as size, wiring, hysteresis and temperature sensitivity will be minimized. The hand will be used for in-hand manipulation and for precise impedance control. Finally, a tactile robot hand will be demonstrated as a proof of concept.

３．研究の方法

We develop a novel 6-axis F/T sensor as well as distributed 3-axis force skin sensors, test their characteristics, implement them on a robot hand, and use them for various tasks.

４．研究成果

Year 1:

We have implemented and tested the 3-axis capacitive force sensor for skin. The main novelty is the tilted capacitive transducers with copper beryllium that enables measuring the tangential forces acting on the sensor surface. Experiments clearly show that the sensor can sense the 3D force vector with a certain level of accuracy. Even after the molding, the sensor has a relatively high SNR. In our experiments, the hysteresis was limited within 4% of the maximum force after the molding when covered with a 7mm-thick layer of Ecoflex Supersoft 30 silicone rubber. The temperature compensation pad can limit the effect of temperature changes on the sensor measurements.

Furthermore, we have implemented a tactile sensor uses Hall-effect sensors. This sensor requires less space and the production is easier than for the capacitive sensor. We implemented a tactile sensor system that can be installed on robotic hands, in particular, the commercially available Allegro Hand from Simlab. Each sensor module contains 16 tri-axial Hall effect force sensors and eight tri-axial accelerometers. The modules are 26mm long and 27mm wide and fit on each of the 11 servo motors that constitute the finger phalanges of the Allegro Hand. The 3-axis Hall effect sensors are close to each other (4.7 from the center of one sensor to the next), but experiments proved that the crosstalk is limited, and the position and shape of the contact can be extracted.

Year 2:

We have implemented the 6-axis F/T sensor based on capacitive sensing. The sensor employs a unique arrangement of the 12 single axis transducers to allow it to measure the 6-axis force-torque while being small in size, light weight and providing digital output (I2C).

Moreover, we further developed and evaluated the soft skin sensor based on Hall-Effect sensing. The sensor can now also be used on a curved surface like a fingertip. The sensor is low-cost, easy to manufacture, and can measure normal and shear forces. The SNR value of 54dB for 0.4N load was achieved, which is relatively high for a soft skin sensor. Several sensor modules were integrated in a robot hand.

We also performed work to optimize the fingertip shape and material and performed in-hand manipulation with the robot hand.

Year 3:

We further developed the sensor and tested it successfully.

We implemented a small-sized 6-axis force-torque sensor, using a novel arrangement of 12 unit of the transducers based on the capacitive force transducer we have previously developed. It provides digital output via I2C bus to reduce the susceptibility to noise and the number of wires. Basic sensor characteristics such as its sensitivity, signal-to-noise ratio,

linearity, and hysteresis have been verified. More importantly, we have verified that our sensor can detect and measure the 6-axis force-torque.

５．主な発表論文等
（研究代表者、研究分担者及び連携研究者には下線）

〔雑誌論文〕（計 4 件）

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〔図書〕（計　　件）

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○出願状況（計　　件）

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番号：
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〔その他〕
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