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Surface Inspection by Tactile Sensing System with Tactile Enhancement Device

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***Abstract*— In this study, we proposed a tactile sensing system for surface inspection. When users trace the surface of the object, the minute unevenness is evaluated. We evaluated the fine shape of the surface by combining the sensor signal from the tactile sensor with tracing position information. In the demonstration, we introduce a prototype of the tactile sensing system.**

Keywords—Sensing, Surface inspection, Tactile enhancement

I. Introduction

In the car production line, there is an inspection where the craftworker inspects the surface of the cars by touch. They trace the surface of the body to check for minute unevenness in the inspection. This minute unevenness is several tens of micrometers in height or depth, and a few millimeters in width. Highly skilled techniques are required to manually search for unevenness on the surface of the car body. In this study, we aim to make surface inspection easy for anyone to inspect.

For precise surface inspection, there are measurement methods that use optical sensors such as surface inspection indicators and lasers. However, these methods are unsuitable for production lines where rapid work is required because they require a significant amount of time. Furthermore, these methods require a clean and well-organized environment that is difficult to prepare on a production line. In this study, we propose a tactile sensor system for surface inspection that can be used in production lines.

II. Propesed method

For the tactile sensor, we used the scanning tactile sensor we developed[3]. The developed tactile sensor has a strain gauge and a flexible structure between the skin and target surface. The flexible structure deforms according to the shape of the target surface, and the deformation was sensed by the strain gauge. The flexible structure has the effect of amplifying minute deformations, an effect called the tactile enhancement effect. In this study, a spiral-structured flexible structure was used[4]. This is a tactile enhancement devise.

We proposed a method that combines the signal from the developed tactile sensor with information on the tracing position as a tactile sensing system for surface inspection. The developed sensor has a signal strength that changes according to the magnitude of the curvature. Therefore, it outputs a signal according to the curvature of the location of the minute unevenness. We made it possible to evaluate the position and shape of minute unevenness using the proposed tactile sensing system for surface inspection.

III. Demonstration

In the demonstration, the participants used the proposed tactile sensing system to trace a microconvex shape and check the tracing position and sensor signal in real time. Four uniaxial force sensors are placed under the tracing surface to

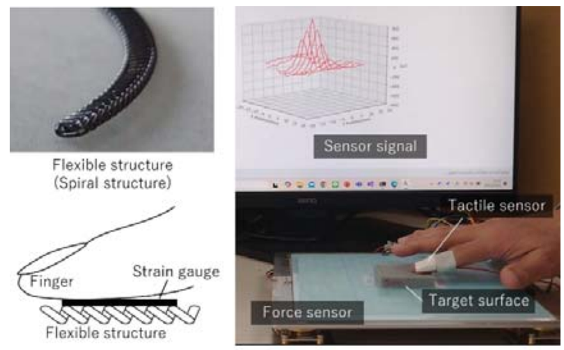
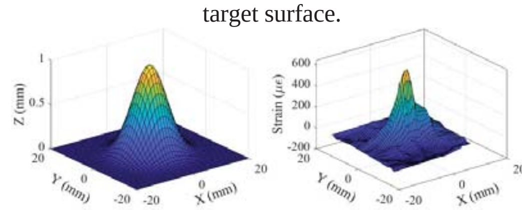


Fig. 1 Demonstration setup: The sensor is worn on the participant's finger and force sensors are placed under the target surface.



(a) (b)

Fig. 2 Comparison of target shape(a) and sensor signal(b)

estimate the tracing position. A Gaussian-shaped target surface was prepared. Figure 2(a) shows the three-dimensional coordinates of the minute unevenness. The center where the curvature is greatest is set as the origin of each. The color map in the graph indicates that the brighter the brightness, the greater is the curvature. Figure 2(b) shows the approximated curved surface of the sensor signal obtained from the sensor signal. The Z-axis shows strain. Comparing the two graphs, it can be observed that the signal is output according to the magnitude of the curvature. A microconvex shape can be evaluated as the curvature of the shape information on the target surface.

Acknowledgment

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References

[1] T. Hirose, “Moiré Deflectometry for Measuring Specular Surface Shpes”, R&D Review of Toyota CRDL, Vol.44 No.4, pp. 17-25, 2013.
[2] Y. Wenzhen, et al. “GelSight: High-Resolution Robot Tactile Sensors for Estimating Geometry and Force.” Sensors, vol. 17, no. 12, 2017.
[3] T. Takei, M. Ando & H. Mochiyama, “Wearable artificial skin layer for the reconstruction of touched geometry by morphological computation”. Advanced Robotics, Vol. 32(21), pp. 1122–1134, 2018
[4] T. Takei, et. al, “ Spiral coil beneath fingertip enhances tactile sensation while tracing surface with small undulations”, Advanced Robotics, Vol. 35(5), pp. 295–307, 2020