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A Practical and Low-cost Contact Force and Contact Position Detection Module for Robot Grippers

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1. Introduction

As robotic manipulators continue to proliferate across various sectors, there is an escalating demand for robots that can handle a wide array of objects with stability and precision. In response, robotic grippers designed to emulate the human hand's form and functionality are becoming increasingly critical. Although previous research has introduced a range of sensor types and structural enhancements to boost the sensing capabilities of grippers[1-3], these advancements often rely on custom or commercially available components that complicate the mechanical and electrical design resulting in increased costs and reduced practicality. For instance, integrating small form-factor force-torque sensors or high-precision tactile sensors at each fingertip involves extensive signal cabling and demands higher computational resources[4], which can hinder real-time responsiveness and control, thereby limiting their practical application[5].

In this study, we introduce a practical contact sensor module employing the lever mechanism, which offers a cost-effective solution for measuring force variations and determining the point of contact force in real time. Its simple design and low-cost sensor components make it not only easy to manufacture but also highly adaptable to various gripper designs. We demonstrate the effectiveness and practical applicability of the proposed sensor module through experimental validations involving the grasping of cylindrical objects.

2. Methods and Results

2.1 Contact Sensing Module Design

Fig. 1 shows the design of the proposed sensor module. In this design, two FSR sensors are used to measure the transmitted contact force. Additionally, four push springs are positioned to provide reactive force to restore the surface when the object's pressure is released. When the robot hand grasps an object, the contact surface is pressed and the contact force is transmitted to the FSRs sensors through a tip. The contact surface is divided into five regions (F1, CF1, C, CF2, F2) and named as shown in the Fig. 2.

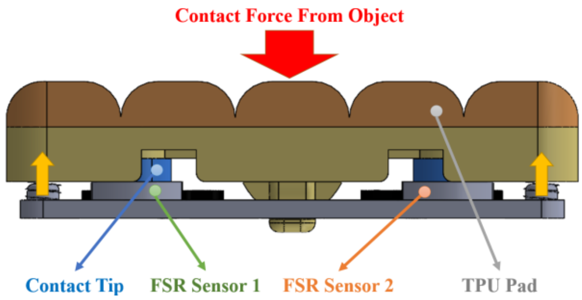

Fig. 1. Design of the contact sensing module.

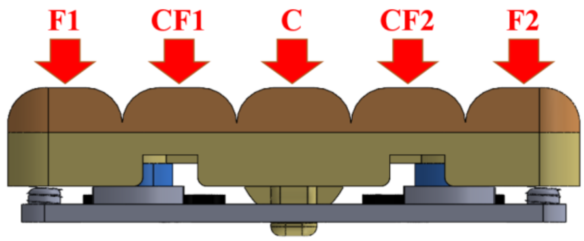

Fig. 2. Test points on the contact surface.

2.2 Performance Evaluation

A series of tests were conducted to evaluate the sensing performance of the gripping detection module. For these tests, a jig was fabricated to securely fix the contact sensing module and apply pressure on the contact surface to simulate the contact force experienced during object gripping. Calibration was first performed for the two FSR sensors installed in the module. As illustrated in Fig. 3, a loadcell combined with a linear stage was fitted with a FSR fitting tip of the same diameter as the TPU tip integrated into the module. Force was applied to the sensing space of the FSR sensors through position control of the linear stage. An Arduino Mega 2560 was used to read signals from the BCL-3L loadcell and the FSR sensors signals, and force-voltage graphs were generated, as shown in Fig. 4. Experiments were performed to measure the contact forces at five points on the contact sensing module's contact surface. the results are shown in Fig. 5. The measured contact forces at each test point generally correspond proportionally to the actual applied contact force. Additionally, the force-sensor output graphs indicate that the force values from the two FSR sensors are similar at the center but exhibit significant bias toward one sensor as the contact point moves away from the center. This trend allows for the determination of gripping points, and suitable compensation algorithms can be applied based on the measured force values to optimize gripping performance.

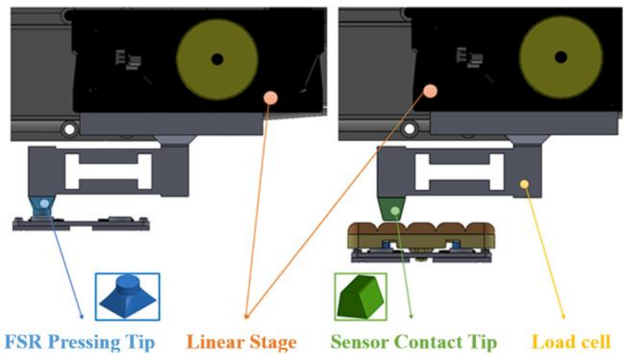

Fig. 3. Experimental setup: Load cell attached on linear stage to press FSR and contact sensing Module

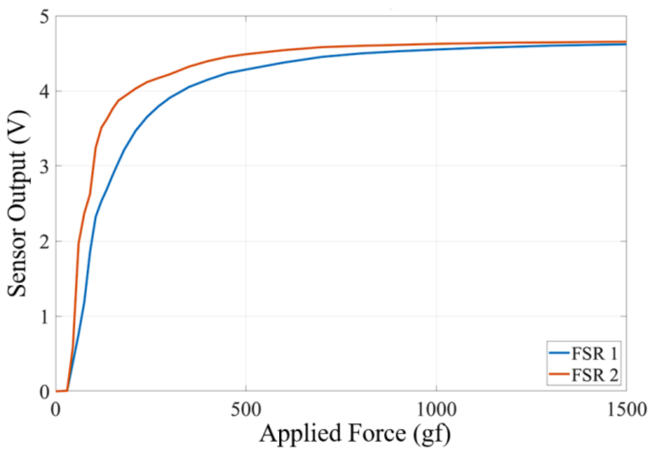

Fig. 4. FSR sensor calibration curve

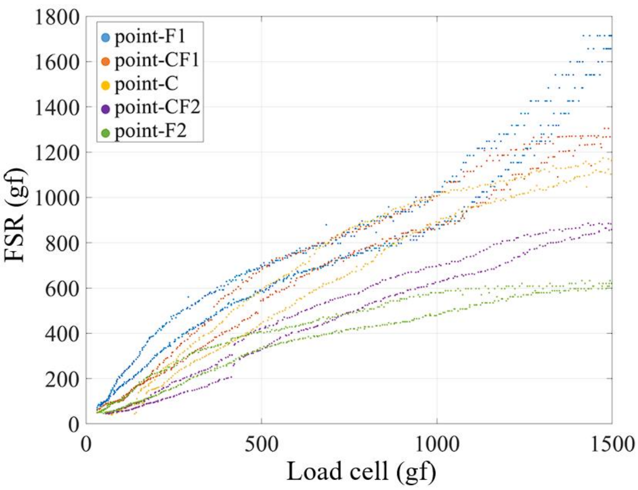

Fig. 5. Evaluation test result.

2.3 Contact Sensing Modules applied to a robot gripper

Experiments were conducted to verify the grasping performance of the proposed contact sensing module. As shown in Fig. 6, the contact sensing modules were mounted on the links of the robotic finger. The figure illustrates a robotic finger composed of two independent links, each equipped with a sensor module. Each link can independently contact an object. Experiments were performed to grasp cylindrical objects using this robotic finger. Fig. 7 shows the contact force applied during grasping was effectively measured by the contact sensing module.

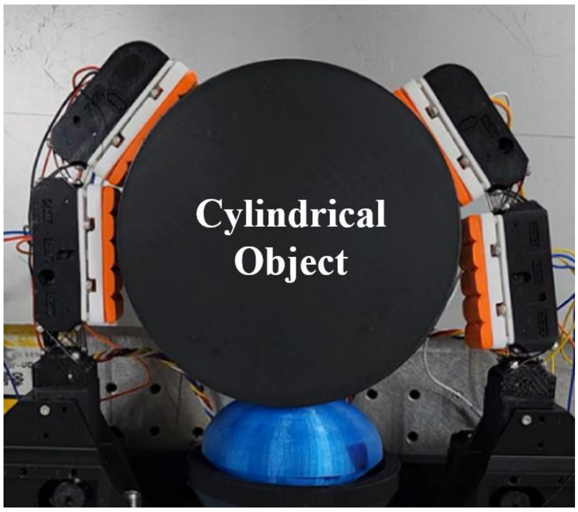

Fig. 6. Contact sensing module placed on the links of an articulated robotic finger.

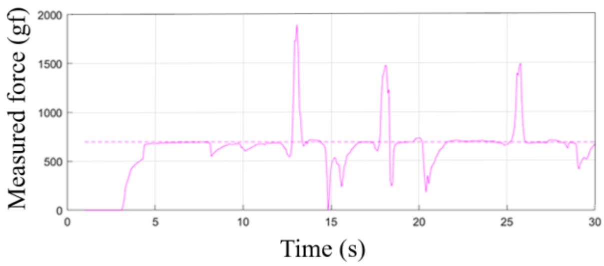

Fig. 7. Force graph measured by contact sensing module during grasping of a cylindrical object.

3. Conclusions

In this study, we proposed a contact sensing module which employs a simple lever mechanism integrated with low-cost FSR sensors. With the help of compensation algorithm, gripping forces and their contact points are measured well enough to be applied to existing robot grippers. Experiments involving the grasping of cylindrical objects confirmed that the contact sensing module effectively detected gripping forces. Further research is required to more accurately measure gripping points and gripping forces, as well as to expand experiments to include a wider variety of objects.

ACKNOWLEGEMENT

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