Grasp Slip Prevention and Object Classification With Underactuated Robotic Hand

Joana Cabrera, Nandita Iyer, Neeli Tummala
University of California, Berkeley, Dept. of Bioengineering
University of California, Berkeley, Dept. of Electrical Engineering and Computer Science

Berkeley | EECS
Electrical Engineering and Computer Sciences
BIOENGINEERING
UNIVERSITY of CALIFORNIA, BERKELEY

ABSTRACT

This project aims to detect and prevent object slippage based on tactile sensor data and classify the rigidity of different objects. Changes in pressure along sequential points on the fingers of a hand can indicate that an object is slipping. This research is applicable in prosthetics for executing reliable grasps and for preventing objects from falling. In addition, knowledge about the rigidity of an object can assist in preventing deformation during grasps.

MOTIVATION

Executing a reliable grasp without the object slipping is a challenging problem in grasping applications. Even if a grasp is initiated successfully, a robot must be able to maintain that grasp until the object is set down. The hand should be able to readjust its grip due to object slipping or the user's movement. This is particularly important when using bionic or prosthetic hands because these grasps often occur in dynamic settings. Since users may not have complete knowledge of the object, being able to characterize the rigidity of an object would help in how the robotic hand approaches a grasp and subsequent reorientation.

LIMITATIONS

Due to several issues with the Reflex Takktile Hand, simplifications were made in the project design. First, the hand has functional sensors on only two out of three fingers. Therefore, all grasps were executed with two fingers and positional calibration had to be done manually, introducing human error. In addition, the tactile sensors on the distal joints of the hand are unreliable. In order to eliminate reliance on that data, grasps were executed using information from only the proximal sensors. In general, the tactile sensor data is noisy and the pressure sensitivity among different sensors is variable and inconsistent, which may be caused by unstable connections and wiring inside the hand.

Because grasps are executed using data only from proximal sensors, certain grasps cannot be executed properly, such as those that require the object to be held only by the distal joints. Moreover, the pressure values obtained from the sensors are limited to integer values, resulting in poor resolution for pressure frequency-based slip detection. Additionally, because the distal joints of the fingers are not actuated and are tendon-driven, they will not bend unless the proximal joints are in full contact with the object. This highly limits the types of grasps that are possible. Although the hand has the capability to change the angle between the two adjacent fingers, this was not utilized in the project because of the broken finger. Therefore, more complex actions such as executing a variety of grasps and reorienting an object while grasping were challenging to accomplish, given the state of the Takktile hand. Ideally, more information from the published hand state could be incorporated into the methods, but most unused data such as the raw and joint angles of the hand are unreliable and noisy.

METHODS

Reflex Takktile Hand
This project uses the Reflex Takktile hand, an underactuated, three-fingered robotic hand by RightHand Robotics. It has 9 tactile sensors on each finger: 5 tactile sensors on the proximal joint, and 4 tactile sensors on the distal joint. Grasps were executed using two opposing fingers and sensors in the proximal joints.

Slip Prevention
This task is separated into two sections: touch detection and slip prevention. Identifying when the fingers are touching an object is required to get an accurate starting point before the hand can adjust its grasp on the object. This is done by monitoring if the pressure values on any of the sensors exceed a threshold of 1.0 (unitless) while the hand is closing on the object. The value 1.0 is used because it is the lowest detectable pressure value on the Takktile hand. After detecting that the fingers have made contact with the object, the Takktile hand will begin slip prevention. To classify slipping, the real-time pressure values in the fingers were compared with previous pressure values at an average sampling rate of 250 kHz. If the difference between these two values exceeds a predefined threshold, it is characterized as a slip. In response, the hand will tighten its grip on the object and will continue to tighten its grip until slipping is no longer detected. The lower the predefined slope threshold, the faster the hand would respond to a slipping object. Figures A and B show tactile pressure sensor readings for an object that is slipping and one that is not.

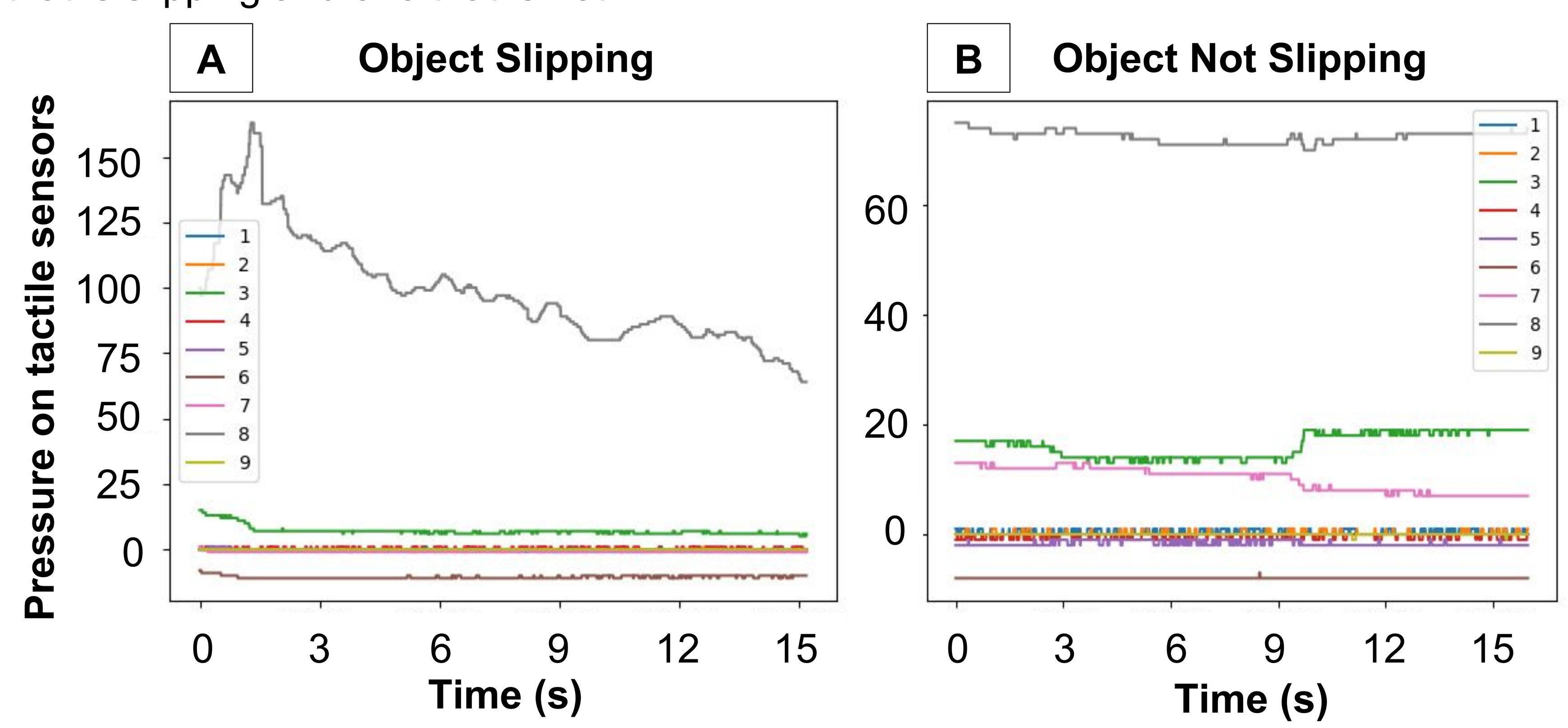

Figure A: Pressure measurements from tactile sensors of one finger while a cylindrical object slips from the hand.
Figure B: Pressure measurements from tactile sensors of one finger while a cylindrical is securely grasped in the hand.

Object Classification
The motor's load on each finger was used to characterize deformable and rigid objects. The Takktile hand first closes the fingers until a touch is detected, just as it was done in slip prevention. Then the pressure threshold is increased from 1.0 to 50.0. If the change in the motor loads is higher than a predetermined threshold, it is classified as a deformable object. Otherwise, it is classified as a rigid object. This method is effectively monitoring whether or not the motors have to do more work to produce a pressure value of 50.0. If this is the case, this indicates that the fingers are able to close a significant amount after a touch was identified. Because the fingers are able to close, this would signify that the object is deformable. The fingers would not be able to close a significant amount if it were a rigid object.

RESULTS

Slip Prevention
Cylindrical, spherical, rectangular, and complex shaped objects were used in this project. Slipping was consistently prevented with all the object types that we used. The hand was able to prevent slipping against someone pulling on the object in addition to slipping solely due to gravity. However, these grasps were heavily reliant on object orientation. For some shapes, increasing the grip will cause the object to slip out rather than securing it, such as a rigid sphere.

Object Classification
The algorithm is able to classify objects consistently and accurately when the hand is gripping spherical or cylindrical objects. However, the classification system does not work as well for rigid objects with sharp edges like rectangular objects. These objects produced inaccurate results and misclassified objects. During these grasps, the fingers would not completely surround the object after stopping at first contact. When the pressure threshold is increased, the fingers could continue to curve due to the complex shape regardless of its rigidity, subsequently increasing the motor load. This significant increase in load is similar to how a deformable object would perform. Since the classification is based on motor load, the system would incorrectly classify a sharp edged, rigid object as deformable. In general, the system is relatively accurate in classifying a wide array of objects with different shapes and densities.

FUTURE IMPROVEMENTS

Several aspects of this project could be improved. To begin, a more reliable hand could be used to get more accurate and consistent data. Currently, two fingers are used, but it would be useful to use three or more fingers to reorient the grasp if an object is slipping rather than just applying more pressure. Furthermore, a more robust method to detect slippage could be utilized. The current method of slip detection using pressure thresholds would not work if the orientation of the hand changes significantly. Thus, using a frequency based slip detection algorithm would be more robust. Although this type of algorithm was attempted, it was limited by the sensor noise and low pressure resolution. In addition, the produced object classifications could be used to modify the behavior of the hand while an object is slipping. Finally, machine learning could be incorporated for slip detection and classification and an actual grip controller could be implemented.

WORKS CITED

Barone, Roberto, et al. "Multilevel Control of an Anthropomorphic Prosthetic Hand for Grasp and Slip Prevention." *Advances in Mechanical Engineering*, vol. 8, no. 9, 2016, p. 168781401666508., doi:10.1177/1687814016665082.

Kent, Benjamin A., and Erik D. Engeberg. "Robotic Hand Acceleration Feedback to Synergistically Prevent Grasped Object Slip." *IEEE Transactions on Robotics*, vol. 33, no. 2, 2017, pp. 492–499., doi:10.1109/tro.2016.2633574.

Su, Zhe, et al. "Force Estimation and Slip Detection/Classification for Grip Control Using a Biomimetic Tactile Sensor." *2015 IEEE-RAS 15th International Conference on Humanoid Robots (Humanoids)*, 2015, doi:10.1109/humanoids.2015.7363558.

Yussof, Hanafiah, et al. "Analysis Of Tactile Slippage Control Algorithm For Robotic Hand Performing Grasp-Move-Twist Motions." *International Journal on Smart Sensing and Intelligent Systems*, vol. 3, no. 3, 2010, pp. 359–375., doi:10.21307/ijssis-2017-397.