Slip Detection on Natural Objects with a Biomimetic Tactile Sensor

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Abstract. Slip detection enables robotic hands to perform complex manipulation tasks by predicting when a held object is about to be dropped. Here we use a support vector machine classifier to detect slip with a biomimetic optical tactile sensor: the TacTip. Previously, this method has been shown to be effective on various artificial stimuli such as flat or curved surfaces. Here, we investigate whether this method generalises to novel, everyday objects. Five different objects are tested which vary in shape, weight, compliance and texture as well as being common objects that one might encounter day-to-day. Success of up to 90% is achieved which demonstrates the classifier's ability to generalise to a variety of previously unseen, natural objects.

Keywords: Slip detection · Tactile sensing · Machine learning

1 Introduction

Humans have highly effective slip detection mechanisms that are deployed when grasping an object. Humans continuously adjust the grasp to prevent an object from being dropped [1]. Meissner corpuscles respond to local skin movements that are present when slip occurs which initiates a reflexive response [2]. Meissner corpuscles are densely populated in the fingertip which is why the human hand is such an effective grasping mechanism. Mimicking the function of the Meissner corpuscles and subsequent response in a robotic hand will yield a more sophisticated sense of touch and enable complex object manipulation by reducing the likelihood of an object being dropped [3].

Slip detection has been a poplar area of research since the 1980s with many different sensors and methods used [4,5]. The aim of this study is to investigate whether a previously developed slip detection method generalises to novel objects. We use the TacTip biomimetic tactile sensor [6]. Previous work with the TacTip has focused mainly on object perception [7,8] so slip detection capabilities will further demonstrate the sensor's versatility.

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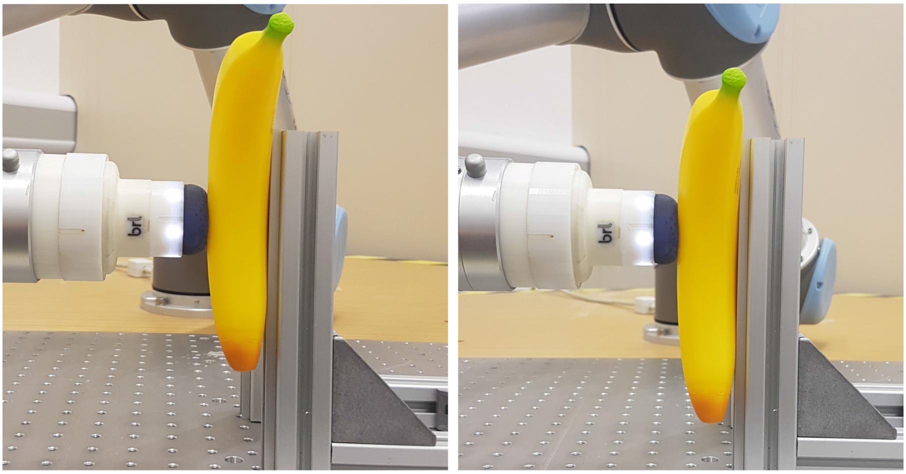

(a) Banana held before slipping (b) Banana caught after slipping

Fig. 1. The experimental setup. An object is secured above the ground by using the tactile sensor to press it against a vertical metal plate. When slip is detected the sensor moves in to prevent the object from falling. A clear drop in height of the plastic banana is evident.

2 Methods

The TacTip is a 3D-printed, biomimetic, optical tactile sensor containing 127 pins on the inside of a soft, compliant hemisphere. A camera is focused on the pins and records their positions when the TacTip contacts an object. The TacTip is mounted on a six degree-of-freedom robotic arm (UR5, Universal Robots).

For this work we use the same classification method described in James et al. [9]. This involves using the velocity of each pin in the TacTip as an input to a support vector machine (SVM). Image capture, processing and classification leads to the data being sampled at 100 FPS.

Being able to detect the velocity of each pin individually is analogous to the Meissner corpuscles which each contain a single nerve fiber capable of detecting slip in its receptive field. This will allow for slip to be detected in objects where contact area varies.

This work, presented by James et al. has already demonstrated a high degree of success at slip detection and preventing objects from being dropped. However, the objects used were regularly shaped, solid objects and a variety of common household objects was not tested. Here, we use the same classifier used to test those objects which is not modified or re-trained in any way.

Fig. 2. The five different objects that were tested for this study. The objects were chosen due to their different shapes, weights and compliances so that an indication of the slip detection method's ability to generalise to random objects can be tested.

3 Experiments

Each experiment proceeds as follows. The UR5 robotic arm - to which the TacTip is attached - presses an object against a vertically mounted metal plate until it is securely held with no slipping. The arm then begins to slowly retract ($0.2\ \text{mms}^{-1}$) until the object slips (Fig. 1).

The data from the sensor is continually being passed through the SVM classifier and if slip is detected the arm moves forward to try to prevent the object from being dropped. The experiment is considered a success if the object is visually seen to start falling, the classifier detects the slip, the arm moved forward and the object is secured against the wall without further slippage. Any other outcomes such as slip being detected but the object still being dropped is classed as a failure.

The five objects chosen were; a paper box containing a plastic cube, a metal coffee container, a mustard bottle, a water bottle (approx. 1/3 full) and a plastic banana. Figure 2 shows each object that was tested. The objects were chosen as each has a different shape, weight, compliance and texture as well as being common objects and shapes that one might encounter day-to-day.

4 Results and Discussion

Each object was tested ten times in the manner described above and the results are summarised in Table 1. The results show that four of the five objects are stopped from falling with a high success of up to 90%. The only low scoring object is the banana which was only stopped 30% of the time. For this case the classifier was able to detect the onset of slip but the shape of the banana meant that moving to re-secure it mostly pushed the banana out of the way and onto the floor.

Table 1. Showing the success at the slip detection method at generalising to a variety of objects. Each object has a different shape, compliance and weight and the slip detection method still performs well.

Object	Success (%)	Mass (g)
Box	90	145
Mustard	80	47
Water bottle	90	186
Coffee	90	97
Banana	30	66

Each object used was novel to the classifier and no parameters of the object were known to the classifier prior to each experiment. This demonstrates the versatility of the classifier to generalise to previously unseen objects.

Having a single tactile sensor moving with a single degree of freedom means that the ability to handle complex objects is severely limited. However, the fact that slip was reliably detected, even on the banana, means that using a gripper with more degrees of freedom is likely to be successful at preventing slipping objects from being dropped.

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