Graduation Research Plan
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1. Research theme

Detection of stable gripping situation for slip prevention by a robot hand gripper

2. Background & Purpose

Slipping detection is one of the unique talents of human tactile sensing. The ability to recognize a wide range of qualities of a gripped object, such as shape, weight, and dimension, is enabled by the sense of touch. Based on these features, the applied force can be adjusted to prevent the grabbed object from slipping. Despite the importance of tactile sensing for humans, tactile feedback is rarely provided by mechatronic hands (robotic manipulators, prosthetic hands etc.). The requirement to grip objects using effective slip prevention algorithms has not yet been addressed by existing artificial manipulators, which are therefore limited to structured environments. Several approaches to the problem of slip detection and correction have been developed in recent years, utilizing a variety of sensor typologies. However, there has been no impact on the industrial market.

For the manipulators handling fragile objects, a precise and definite slipping detection is mandatory. In those environments, this research sees an importance of slipping detection during the process of gripping. This research will focus on detecting if the process of slipping is stable after the gripper has caught the object and before lifting it. In terms of stability, two states will be distinguished: “Stable”, which means the object is firmly grasped, and “Unstable”, which means the object may be slipping from the robot hand gripper.

3. Research goal

Slipping situations are occurred by diverse causes. For instance, when the gripping force is not to the center of the object or if the wrong texture of the surface is chosen to grip. The gripping strategies used by humans mainly depend on the purpose of gripping, the object surface and the size of the object[1]. This research will focus on why slipping happens related to the purpose of gripping. Most of the time the purpose of gripping is to make sure the object they desire to hold remains stable after gripping. Therefore, human grasps an object and feels the object is slipping, they retry and give more force to it to make sure it will not slip and fall. The goal of this research is to detect non-deformable objects' stable gripping situation to prevent slipping by automatically handling gripping force in real-time.

4. Research tasks

In this research, gripping situations will be demonstrated using a Rotrics robot arm[2](Figure1), Keigan motor[3](Figure2) and Micro Electromechanical Systems (MEMS) tactile sensor [4](Figure3). 5mm cylinder will be attached to the Keigan motor to demonstrate different applied forces with stable and unstable gripping situations and the data. Utilizing the collected data, the diverse types of neural networks will be implemented to achieve the best classification result. The best type of neural network will be applied to demonstrate the gripping situations using real objects (books, paper cups, plastic cups etc.) in real-time.

Figure 1.Rotrics robot arm

Figure 2. Keigan motor

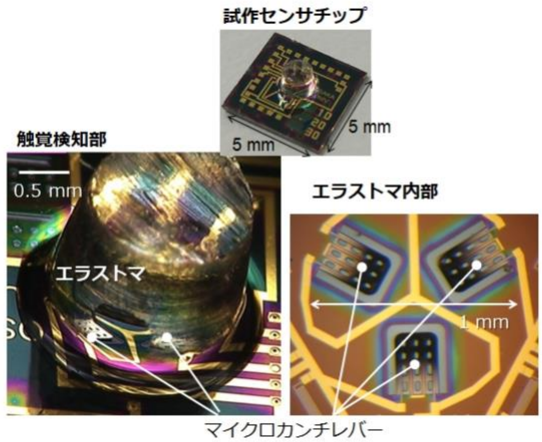

Figure 3. Prototype of MEMS tactile sensor

Research Challenge 1: Development of Measurement

The provided environment should not adversely affect the results in the measurement. There is a need to develop a durable and miniaturized measuring device capable of measuring the slipping of an object inside the gripper of a robot hand. It is also a task to transmit recorded data while maintaining a constant experimental environment.

Research Challenge 2: Neural Networks for Collected Data

The purpose of this study is to find the best neural network for the implementation of real-life object slip detection. The challenge is to develop different types of neural networks and improve the accuracy of each one of them. It is also necessary to understand how each neural network is structured and modify the data to fit into different neural network types.

Research Challenge 3: Development of Real-Time Feedback System

The goal of this research is to prototype a real-time feedback system to detect the slipping situation. Construction of the system flow to demonstrate this real-time feedback with the interaction between the robot hand gripper, machine learning output and Arduino is a challenge. Another challenge is figuring out how to make the gripping stable after the machine learning outputs the grip is unstable.

5. Solutions

The solution to the research tasks shown in 4 is shown below.

Solution 1:

Use MEMS tactile sensor and 3 channels amplifier (FSamp4) for MEMS tactile sensors (Figure4) developed by MxD lab. MEMS tactile sensor with of width 1mm and height 1mm is small enough to measure the slipping of an object inside the gripper of a robot hand(Figure5). This sensor used with an amplifier will measure three channels outputting mV in LSB units corresponding to time through Arduino. FSamp4 outputs those three channels with the frequency of 800Hz per second. Measured data can be used as raw data itself or be plotted into graphs for different neural networks. The three output signals can be recorded directly into a CSV file via excel. Based on real-life slipping situations where the slipping is done within milliseconds, the dataset will be cut in every 80Hz for 100ms. As the MEMS tactile sensor is sensitive, the experimentation should be done with a dummy sensor first. When the ideal environment is guaranteed, the sensor should be changed to a fully functional MEMS tactile sensor for accurate data collection.

Figure 4. MEMS tactile sensor inside the robot hand gripper

Solution 2:

Try out different types of neural networks with the dataset gotten from the MEMS tactile sensor. The development will focus on commonly known neural networks first such as 2DCNN, 1DCNN, LSTM and RNN. To handle different types of neural networks and modify data structures, read through papers and machine learning related books. Analyze the test result, neural network structures and data collection through the use of confusion matrix and loss and accuracy results and improve them. With the best performed neural network implement it in the real object experimentation. The aim of the accuracy for the best performed neural network is set as 95%.

Solution 3:

For a robot hand gripper to handle real objects the vulnerability of the sensor tip must be taken into place. Gripper needs to widen the gripper to its maximum value first and narrow it down until it encounters the target object analyzed via the signal outputs from the MEMS tactile sensor and FSamp4 amplifier. Then the real-time machine learning implemented for the classification of stable situations will output that the grip is not stable or stable. This research plans to classify the state of being unstable into two kinds of unstable slips: rotation slip, defined as circular movement around the gripped point, and regular slip, defined as slipping down straight down from the gripped point. Resulting in three kinds of labels for the output: stable grip, rotation slip and regular slip. The corresponding gripping situation will give feedback to the robot gripper. If the output is stable the robot hand will move on to detect the next target object. For the rotation slip and regular slip, it is interpreted as not enough force is being given for a stable gripping situation. Thus, an increase in the gripping force will be applied for a stable grip. The aim of the accuracy for this real-time feedback system is 95%.

6. Schedule

Reference:

[1] Edussooriya, C. U., Hapuachchi, H. S., Rajiv, D., Ranasinghe, R. A., & Munasinghe, S. R. (2008). Analysis of grasping and slip detection of the human hand. *2008 4th International Conference on Information and Automation for Sustainability*. https://doi.org/10.1109/iciafs.2008.4783973

[2] Rotrics robot arm picture
https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.reichelt.com%2Fde%2Fen%2Frobotic-arm-dexarm-luxury-kit-rotrics-dex-lkit-p287159.html&psig=AOvVaw1xmqAzivgwfZ3BwwyWYlAe&ust=1650521239567000&source=images&cd=vfe&ved=0CA0QjhxqFwoTCNCeifb8ofcCFQAAAAAdAAAAABAV

[3] Keigan motor picture
https://keigan-motor.com/km-1s/

[4] MEMS tactile sensor picture
http://sensait.jp/8111/