RoboGripper

A Force Sensing Gripper for Sawyer Robotic Arm

ELECOMP Capstone Design Project 2020-2021

Sponsoring Entity:

Intelligent Control & Robotics Lab. (ICRL)
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Entity Overview:

For more than 50 years robots have been confined to manufacturing facilities and other specialized application fields. But robotics technology is getting ready for widespread adoption and integration in human society. New applications of mobile robots both for professional use and for the general public are being invented at an increasing pace. At the same time, new challenges arise when robots break free from the known controlled environment of factories to move into the wide world.

The Intelligent Control and Robotics (ICRobots) laboratory at the University of Rhode Island is a world class research lab specializing in mobile and aerial robotics and multi-robot systems. Our vision is to bring cutting-edge robotic technology to application and consumers to contribute to a better future.

The ICRobots lab includes three directing faculty members, from 2 different departments, six graduate students and several undergraduate students, with almost $2M in research funding from many state and federal agencies.

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Project Motivation:

Industry 4.0 uses smart technology and real-time data to increase productivity and reduce costs. In smart factories, machinery, storage systems and production are capable of carrying out complex tasks, exchanging information and giving instructions to each other without the need for human involvement. In the factory of the future, repetitive or difficult tasks are taken over by robots that are becoming increasingly sophisticated machines. But as cognitive capabilities of robots increase, so does the demand for dexterous manipulation and flexibility.

Still unrivaled by their robotic counterparts, the human hand is the ultimate tool to accomplish a great variety of tasks, be it manipulating small objects, applying strong forces, or gentle touches. Its strength comes from the independent actuation of all fingers, as well as from the ability to sense and control the force applied by each finger. Taking as model the human hand, the ICRobots lab aims to equip its robotic arm and its mobile robots with a versatile gripper. However, high manipulation capabilities come with a hefty price tag, with high-end robotic hands ranging in the scale of tens of thousand dollars. The goal of this project is the design and implementation of a versatile low-cost three-fingered gripper with force sensing capabilities.

The availability of a reliable low-cost gripper will allow the ICRobots lab to include our robotic arm in our multi-robot setup. We will be able to develop and test algorithms that include, for example, an information collection role for our mobile robots, and an operative hands-on role for the arm. Moreover, being low cost, in the long term we will be able to replicate it and install it also on our mobile ground vehicles.

Anticipated Best Outcome:

The anticipated best outcome (ABO) of this project is a fully functional prototype of a three-fingered gripper working while mounted on a Rethink Robotics Sawyer arm. Each finger should be independently actuated and provide measurements of the contact force in one or more location on the finger. The structural components should be realized in 3D printed material in order to keep down the cost and weight. Moreover, each finger should be realized with two or more articulated joints, with one finger mimicking the thumb. The gripper is expected to be able to grasp and hold small objects as a tennis ball, a screwdriver, and a pen.

The actuation of the fingers should be provided by multiple motors or servomotors. The motion of the motors can be transferred to the links of the fingers through cables, small pistons, or other gears. Force sensing resistors or other force sensors should be embedded in the design in multiple locations of the arm, one or two for each finger and one or more in the palm. Actuators and sensors should be driven by a microcontroller (MC) as Arduino or Raspberry Pi. The whole device should be attached comfortably to the robotic arm without limiting its motion. The gripper should be independently powered with an external power supply, and the MC should be interfaced with a base station (BS) on the back of the ARM through USB, with the USB cable and the power cable running along the arm. Alternatively, a wireless solution can be investigated with the gripper powered through a battery and the MC connected to the BS via wifi, XBee or ZigBee. The firmware for the MC and the software on the BS should be developed in Ubuntu OS and compatible with the Robot Operating System (ROS) development suit.

Additional features that go beyond ABO would be:

- Implementation of an arm/gripper simulator in ROS/Gazebo
- An adaptor for integration on a 25 cm mobile ground vehicles

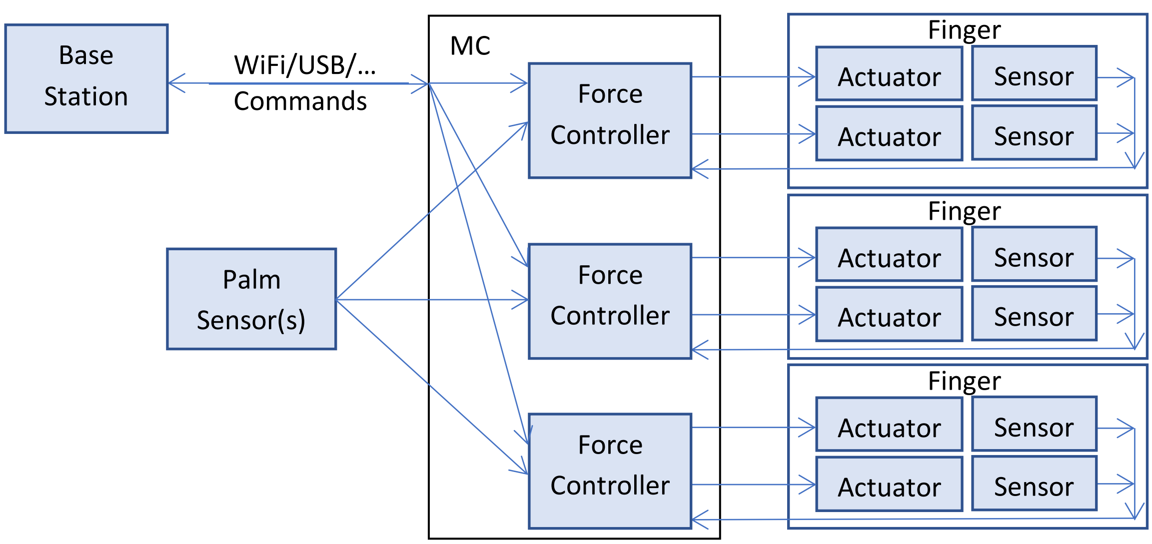
Project Details:

This project has a substantial component of hardware design, both in terms of designing the mechanical structure of the gripper, and the embedding of the electrical components. One of the main challenges will be the design of the articulated fingers. It is expected that each finger will have at least two independently actuated joints. The motors actuating the joints should not be embedded in the finger, but rather stay in the palm of the gripper and their rotational motion should be transferred to the joints by the use of cables, gears, pistons, or other means. Each finger will also need to be equipped with one or more force sensors (force sensitive resistors, load cells, etc.) in the fingertips, but also in the middle joints. Moreover, additional on or more sensors should be embedded in the palm.

The motors and sensors will be connected through appropriate wiring to the MC. The role of the MC will be to drive the motors and collect the sensor readings. Depending on the selected types of actuators and sensors, they may need to be connected to in/out digital pins, I2C, I2S, or other interfaces, and analog in pins. The MC should be selected as to satisfy the needs of the project. To interface the various components with the MC, appropriate firmware will be developed. This can be done in parallel with the mechanical and electrical development. Lastly, the MC will need to provide a mean to interfacing with the BS that could be a serial port, or a wireless connection. The MC firmware will also include a control loop on the force applied by each finger. During a grasping task, the fingers apply a force on the grasped object. A too low force will result in the object slipping off the gripper, while a too strong force may result in damages. Using the measurements from the sensors, the MC will need to establish the appropriate action for each actuator in order to keep the applied force to a safe level.

The last component of this project will be the software on the BS. Its basic functionality will be to receive open/close inputs from an operator, send the appropriate commands to the MC, and receive the force measurements. The BS software will be delivered in the form of a ROS package and will rely on ROS for many of its functionalities, as accepting the user input, setting parameters, and launching the developed executables.

The level of integration that we are looking for is that of a fully functional gripper that can be attached to the Sawyer arm, exchange data with a base station, and grasp small objects of different shapes as a tennis ball or a screwdriver.



The Product:

If the ABO is achieved, the team will have created a gripper that can:

- Be attached to the Sawyer arm
- Grasp a tennis ball and a screwdriver
- Be commanded from a base station
- Send sensor readings to the base station

Hardware/Electrical Tasks:

- Design, 3D print and assemble the structural components
  - The design depends on the selected components and type of transmission
- Determine layout and wiring for boards, actuators, and sensor

Firmware/Software/Computer Tasks:

- Firmware for the MC will be written in C or C++
  - Modular code will be essential
  - Force control loop will need real time reading of sensors and a control algorithm to translate those into commands for the actuators
- ROS-based software for the BS will be written in C++
  - Implement one or more ROS packages in Linux OS to interface with the MC
  - Modular code will be essential
  - Reuse available opensource ROS packages as much as possible

Joint Tasks:

- The organization of the software and its integration with ROS will require great concert effort. All team members should familiarize themselves with:
  - GNU/Linux OS and in particular Ubuntu (a great place to start is here https://www.theconstructsim.com/robotigniteacademy_learnros/ros-courses-library/linux-for-robotics/)
  - ROS with Python https://www.theconstructsim.com/robotigniteacademy_learnros/ros-courses-library/python-robotics/
  - ROS with C++ https://www.theconstructsim.com/robotigniteacademy_learnros/ros-courses-library/ros-courses-ros-basics-in-5-days-c/
- Selecting individual electronic components
  - The choice of MC depends on a tradeoff of interface offering, cost, weight, size
  - The choice of actuators depends on the type of transmission, maximum torque available, size, weight, and cost

- The choice of sensors depends on a tradeoff on operating range, accuracy, size, weight, and cost
- Testing: later on in the project the gripper will need to be mounted and tested on the Sawyer arm in the ICRobots Lab

Composition of the Team:

1-2 Electrical Engineers & 1 Computer Engineer

Skills Required:

Electrical Engineering Skills Required:

- Embedded programming
- Experience with fast prototyping and 3D printing
- Familiarity with computer architecture
- Familiarity with control systems, robotics or concurrent enrollment in ELE456 is a plus

Computer Engineering Skills Required:

- C/C++
- Experience with embedded programming
- Familiarity with software architecture and organization
- Experience with control systems is a plus

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact

The availability of a gripper for the Sawyer arm will allow us to use the robot to its fullest potential. Current algorithmic and application development is limited by the impossibility to really interact with the objects. Leveraging on this new asset, the laboratory will be able to extend its research activity to develop and propose novel algorithms and applications in manufacturing, dexterous manipulation, gasping, and human robot interaction. In the long term, the laboratory also plans to replicate the gripper and mount it on mobile robots, extending its range of activities to mobile manipulation. This will further allow the ICRobots lab to grow in its contribution towards robotics knowledge and increase its national and international reputation in the scientific community. With higher reputation and a novel platform to test with, the laboratory will be able to attract more funding from federal and state agencies.

Broader Implications of the Best Outcome on the Company's Industry:

A successful outcome of this project will help the ICRobots laboratory to grow in size and improve the quality, quantity and variety of its work. On the one hand, an increase in research funding will allow the lab to expand its organic and offering more graduate and undergraduate research assistantship.

On the other hand, the laboratory is always engaging the general public with demonstrations and participating in social events with the purpose of showing the potential of robotics to enhance and assist human society, with a particular focus on the younger generations. The developed platform will be a great showcase to familiarize people with robotics and attract students to the URI's ELECOMP Capstone Design Program.