Integrating New Sensors with LTLMoP

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1. Overview

This project aims to integrate force sensors on Johnny 5 robot with LTLMoP. It will be helpful to have the robot identify if an item is in its hands and use that information for further applications. Force sensors are attached to both hands of the robot. Sensor handler of Johnny 5 is updated to interface with these sensors, and sensor information can be retrieved and used as conditions for control purpose in LTLMoP specifications. For example, Johnny 5 will be able to comply with command "do grabLeftHand if you are sensing itemInLeftHand", which calls actuator function grabLeftHand as long as sensor function itemInLeftHand returns true. Communication with force sensors will be via the onboard SSC-32 servo controller and XBee, which are convenient and versatile.

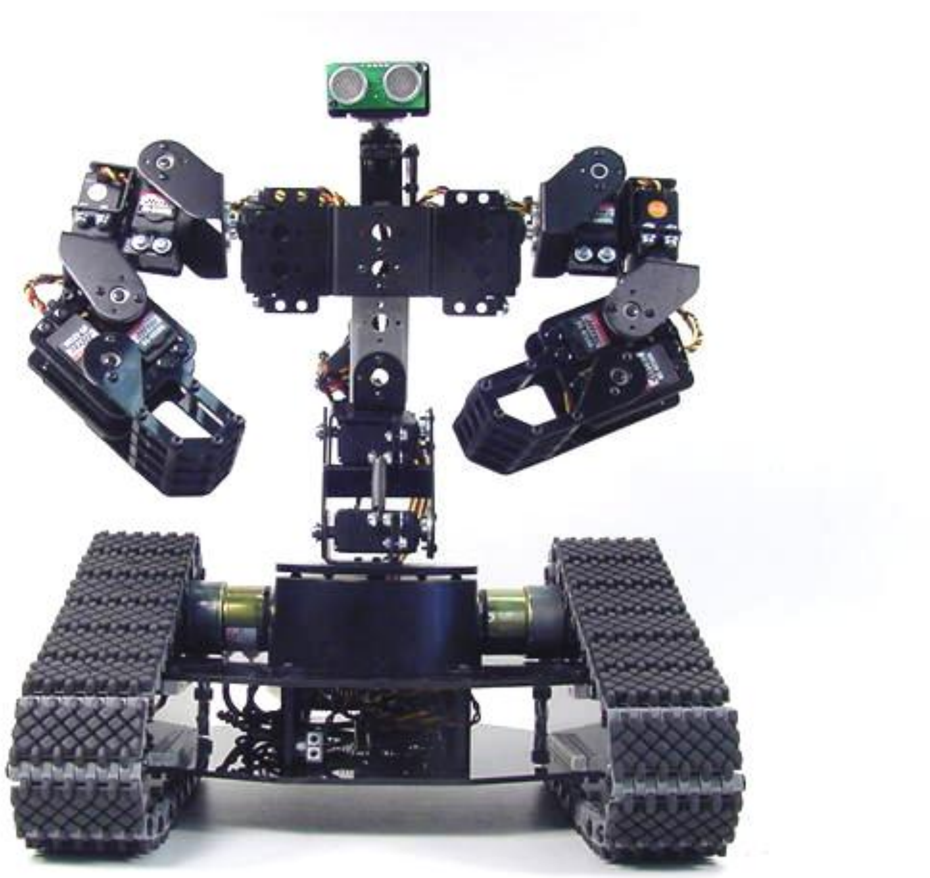

Figure 1. Johnny 5 picture

2. Integrating Force Sensors

Interlinks Electronics FSR 402 force sensor is used in this project. It has very compact size and its sensitivity is optimized for human touch control, which makes it suitable for robotics applications. The specifications of the sensor[1] are shown below:

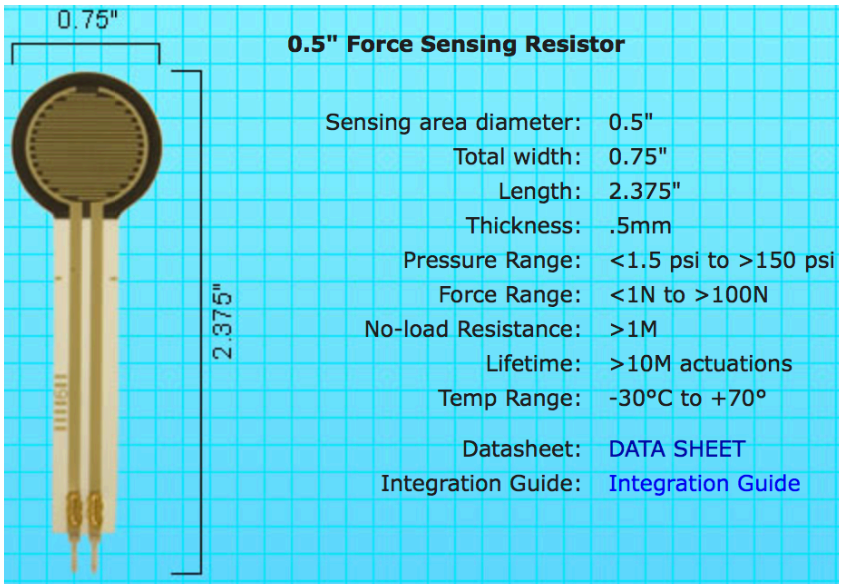

Figure 2. FSR 402 force sensor specifications

To appropriately configure the force sensor, couplers and voltage dividers are used and they come with the sensor kit package as presented in Figure 3.

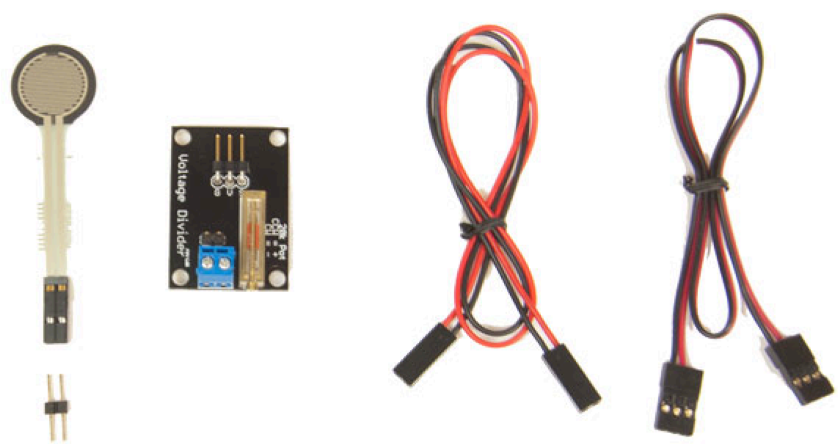

Figure 3. Force sensor kit

[1] Data from http://www.trossenrobotics.com/5i-Force-Sensing-Resistor-Kit.aspx

Two force sensors are installed on Johnny 5, with one attached to each hand. As the SSC-32 servo controller is able to read analog input directly, no additional microcontroller is needed. The servo controller has ABCD input pins adjacent to the BAUD rate selector, inputs A and C are used to read off analog sensor information from right hand force sensor and left hand force sensor respectively. Connections of both force sensors and XBee on the servo controller are indicated below.

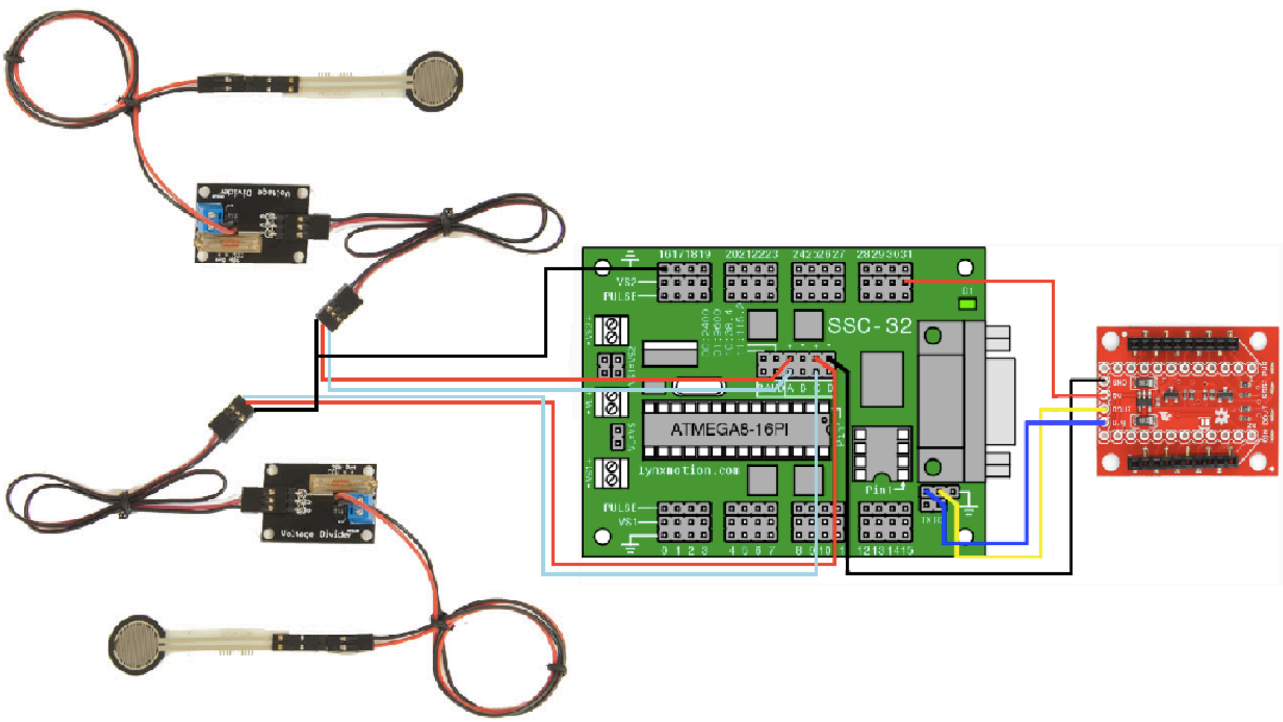

Figure 4. Wiring of force sensors and XBee on SSC-32 servo controller

In order to read analog inputs, the following request command is sent to the servo controller:

VA VC \r

Where:

VA and VC - input ports to read from

\r - required format that specifies carriage return to end the command

It should be noted that at start the ABCD inputs are configured for digital input with pullup. The first time a V* comment is sent, the pin will be converted to analog mode without pullup. Hence, the result of the first read will not return valid data.

The servo controller then returns one byte binary value for the voltage on each requested pin. A return value of 0 represents 0V, and return value of 255 indicates +4.98V. The expected integer value can be calculated from equation:

$$\textit{Sensor return value (int)} = Voltage/5*255$$

For example, if voltage on pin A is 2.0V, it is expected to have a return value of 102. For the force sensor, 0 means no touch is sensed while 255 corresponds to the maximum force it can detect. From tests on the force sensor, it is observed that typical return value is around 100-200 when the robot hand grasps an item.

Since analog inputs for 2 pins are requested, 2 bytes should be read from serial port each time and each byte will be converted into integer within range 0-255. This value indicates the strength of force and will be used afterwards.

The final installation of force sensors on the robot is shown in figure below. This configuration ensures a decent amount of contact when an item of most shapes is captured in the hand.

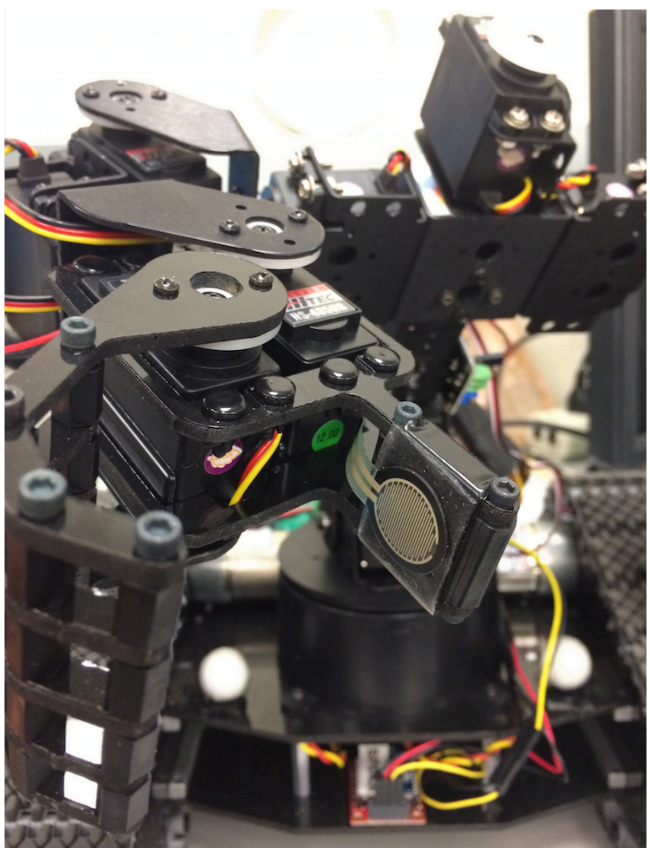

Figure 5. Installation of force sensor on Johnny 5

3. LTLMoP Handlers

3.1 Actuator Handler

In order to integrate and test the force sensors, two actuator functions are created in actuator handler, namely liftArm and closeHand. Both functions take in inputs of a boolean value called actuatorVal and a user-defined argument specifying the arm/hand to move, which will be a string "left" or "right". If actuatorVal is true, liftArm will lift the designated arm and closeHand will close the assigned hand, otherwise liftArm will put down the specified arm and closeHand will open up the hand. Input actuatorVal is set true when the function is called in LTLMoP specifications, and it becomes false if "not + function name" is executed. For instance, given an actuator called liftLeftArm, we can have "do liftLeftArm" and "do not liftLeftArm" in a LTLMoP specification for two opposite actions. In this way, the actuator function is guaranteed to be deterministic and conflict is avoided, for example, the robot will never do lift left arm and put down left arm simultaneously.

The "left" or "right" user input could be entered in proposition mapping, which simplifies the work. Both functions send out a set of servo values and have the robot achieve the desired action within a specified time span.

3.2 Sensor Handler

Function itemInHand is created in the sensor handler to interface with force sensors. It takes in two user defined inputs, one is left or right hand and the other being the threshold value above which force sensor is considered triggered. A default threshold of 100 is used if no user input is entered. These arguments are passed to LTLMoP in proposition mapping when configuring simulation.

As mentioned in last section, to read the sensor data a request message must be sent to the input pin. Serial read of 2 bytes is then executed. From tests in the lab it is observed that occasionally the serial read doesn't return any data, this could be due to request sent being too fast and the controller fails to response. Therefore, a while loop is inserted to ensure data read from sensor is 2 bytes.

Once the sensor data is converted to integer in range 0-255, it is compared to the threshold value. If it is larger than the threshold it means that force sensor in the designated hand is compressed and an item is in this hand, the function will therefore returns true. Otherwise the hand is considered empty and the function returns false.

4. LTLMoP Specifications

In the final project demonstration, a custom-made region map is shown below. To start, Johnny 5 will be placed in region r3 and try to go to r1. As long as Johnny 5 finds me wearing a Vicon helmet within a certain distance, it stops and stretches out both hands to try grasping an item. It will open and close both hands in sequence indefinitely when it is near me until the force sensor in either hand senses an item. If the item is in its left hand, it will travel to region Charge. Otherwise if the item is in the right hand, it will go to region Upload. When the robot arrives at the destination it will stand still and wait indefinitely until I show up. If it detects me in its vicinity, it will then put forward the hand grabbing the item and release it. The corresponding LTLMoP specification is also presented.

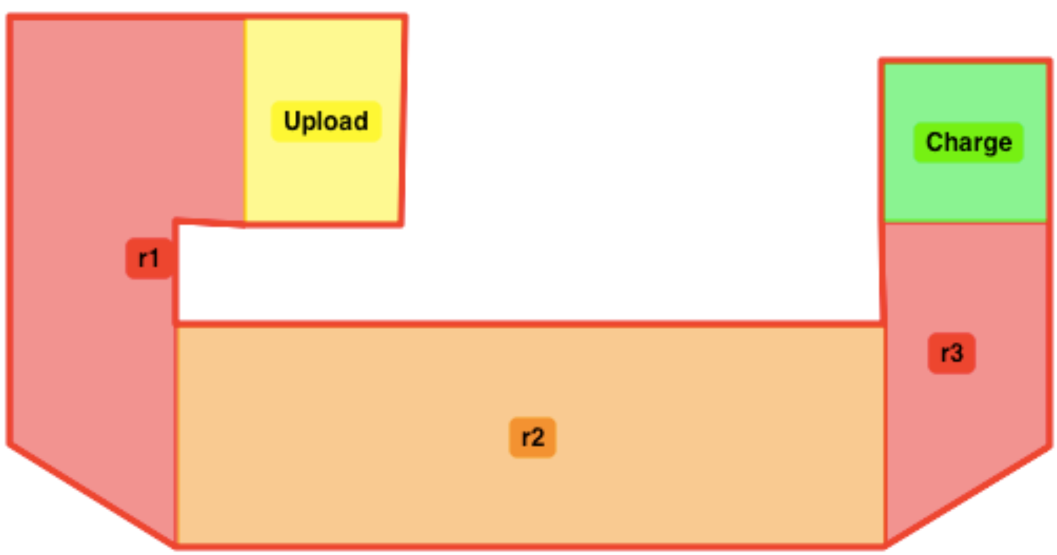

Figure 6. Region map in LTLMoP

```
# setup initial conditions
robot starts with grabLeftHand and not liftLeftArm
robot starts with grabRightHand and not liftRightArm

if you are sensing findMe then stay there
infinitely often not findMe

# keep hands closed and down when moving
if you are not sensing findMe then do (grabLeftHand and not liftLeftArm)
if you are not sensing findMe then do (grabRightHand and not liftRightArm)

# raise arms if findMe is true
if you are not in (Charge or Upload) and you are sensing findMe and you are not sensing itemInLeftHand then do liftLeftArm
if you are not in (Charge or Upload) and you are sensing findMe and you are not sensing itemInRightHand then do liftRightArm

# after raising arm, open hands if not sensing item in hand
if you are not in (Charge or Upload) and  you were activating (liftLeftArm and grabLeftHand) and you are not sensing itemInLeftHand and you are sensing findMe then do not grabLeftHand
if you are not in (Charge or Upload) and  you were activating (liftRightArm and grabRightHand) and you are not sensing itemInRightHand and you are sensing findMe then do not grabRightHand

# close hand and try to grab item
if you are not in (Charge or Upload) and you were not activating grabLeftHand and you are sensing findMe then do grabLeftHand
if you are not in (Charge or Upload) and you were not activating grabRightHand and you are sensing findMe then do grabRightHand

# if sensing item in hand, put down arm and keep closing hand
if you are not in (Charge or Upload) and you are sensing itemInLeftHand then do (grabLeftHand and not liftLeftArm)
if you are not in (Charge or Upload) and you are sensing itemInRightHand then do (grabRightHand and not liftRightArm)

# if robot arrive in designated region, release item in hand
if you are in Charge and you are sensing findMe then do (liftLeftArm and not grabLeftHand and grabRightHand)
if you are in Upload and you are sensing findMe then do (liftRightArm and not grabRightHand and grabLeftHand)

if you are sensing itemInLeftHand then visit Charge
if you are sensing itemInRightHand then visit Upload
if you are not sensing (itemInLeftHand or itemInRightHand) then visit r1
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Figure 7. LTLMoP specifications