



Using MATLAB's ROS Toolbox with Raspberry Pi Controlled Robots to build skills in an introductory programming course

Course: Computer Solutions for Engineering Problems

- Engineering majors
- 64 students per section
- 2 credit hours
- 1 of 4 core courses in UT's Engineering Fundamentals curriculum
- Sophomores, Juniors, and Seniors



Programming in an Active Learning Classroom



- Collaboration tables
- Modular Tables and capacitive touch smart screens accommodate teams of any size
- Zoom breakout rooms used to build and test programs as a team
- *remote control* allows remote users to control robot and contribute to the code



Sphero RVR Platform

Sphero API allows for external raw motor control

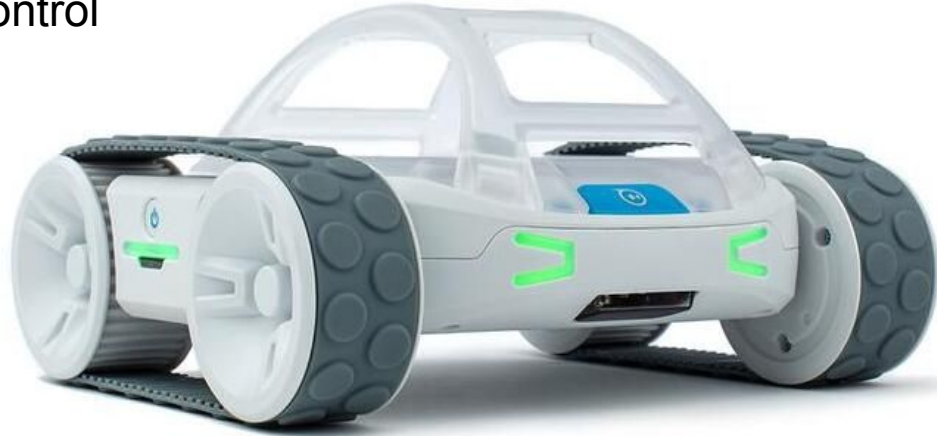
9-axis IMU, accelerometer, gyroscope

Status variables

- position, orientation
- speed, velocity XYZ, angular velocity, acceleration
- heading, battery level, velocity
- ambient light
- riding surface RGB color

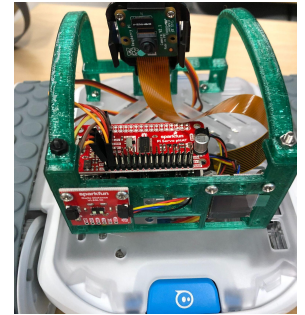
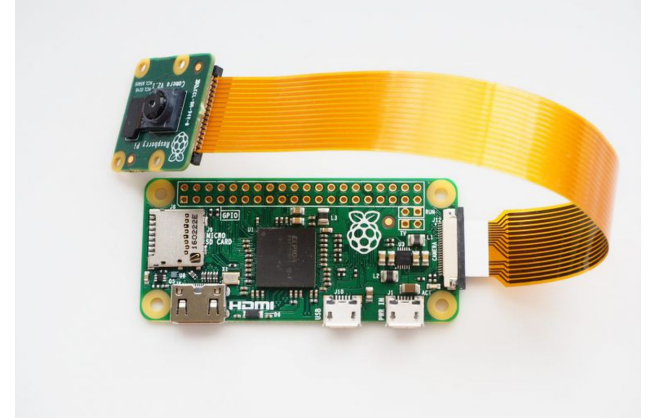
Send/Receive IR for robot follow (future)

Individually addressable RGB LEDs (future)



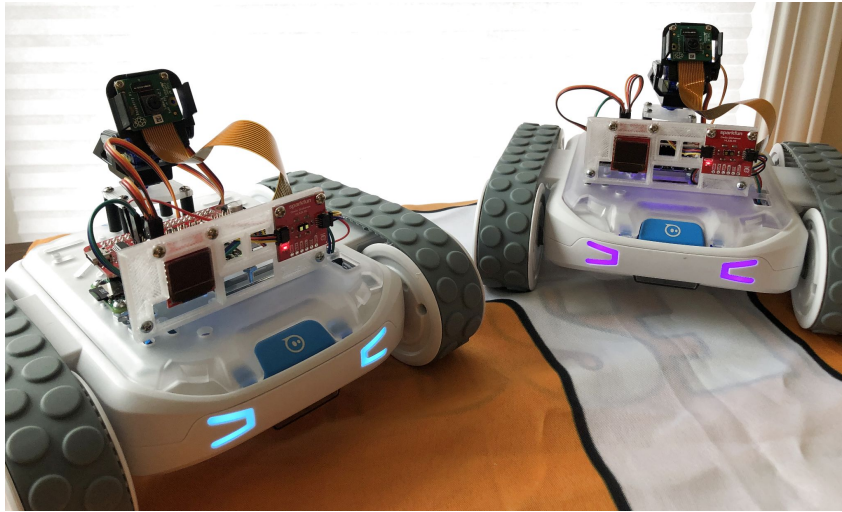
Raspberry Pi Zero

- on-board 802.11b/g/n Wireless LAN adapter
- video camera: video feed, image acquisition and analysis capabilities
- Micro OLED for displaying graphics or text (e.g. sensor readings)
- ToF (Time of Flight) Distance sensor - 40mm to 4m away for refined obstacle avoidance
- servos on ServoPWM Hat for pan/tilt camera
- Good platform for adding features



Our Fleet

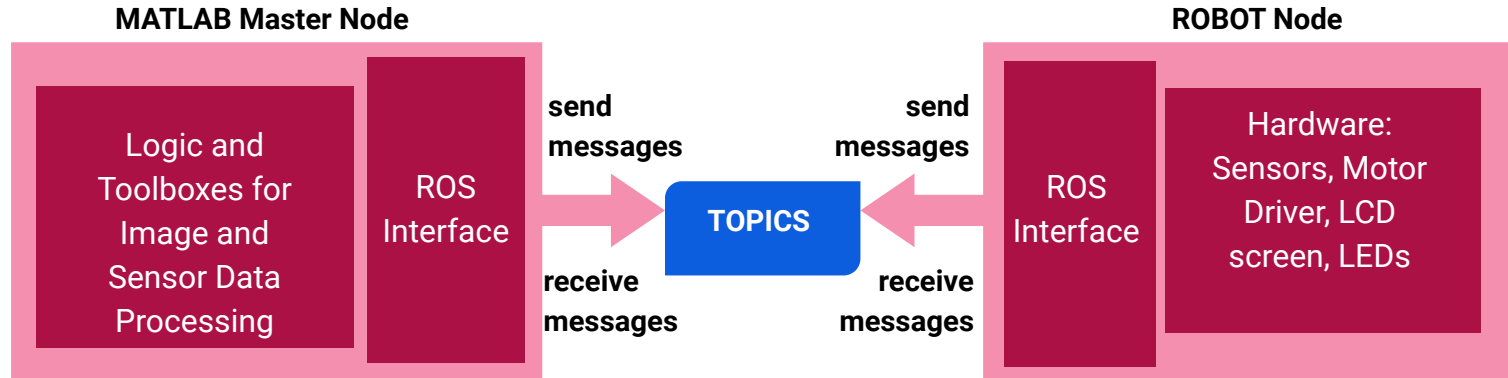
- 43 robots
- ~\$280 each
- custom 3D printed mounting plate / roll cages
- Students can design and 3D print accessories and add sensors and components



MATLAB ROS Toolbox

Bridge to communicate between MATLAB and Python on the Pi

- **Nodes** - Computers processing computations - MATLAB user & Robot Pi - listen, pull, and post info
- **ROS Master Node** - provides name registration and lookup for all nodes
- **Messages** - Nodes communicate with each other by passing messages, a data structure containing fields.
- **Topics** - Nodes send messages by publishing to a topic, and receive messages by subscribing to a topic to get information. Great for many-to-many one-way communication such as getting sensor readings.
- **Services** - Request / reply paradigm where client nodes send messages to server nodes which send information back to client. Great for giving motor control commands as server can give status updates.



Example ROS Topics

All users and robots (nodes) can publish/subscribe to multiple topics

- sphero_msgs/DriveControlAction
- sphero_msgs/DriveControlActionFeedback
- sphero_msgs/DriveControlActionGoal
- sphero_msgs/DriveControlActionResult
- sphero_msgs/DriveControlFeedback
- sphero_msgs/DriveControlGoal
- sphero_msgs/DriveControlResult
- sphero_sensors/color_detected
- sphero_sensors/ambient_light
- sphero_sensors/position
- sphero_sensors/velocity
- sphero_sensors/speed
- sphero_sensors/imu



Compatible with Mac, PC, and Linux,
System Requirements: MATLAB 2019b,2020a&b,2021b, Support Pkg
for Raspberry Pi, Python, C++ compiler, CMake

Robots in the Classroom

Fun factors

- watch programs in action
- test, debug, improve
- engineering design process

Real World Design Factors

- environment
- variability
- repeatability
- lag
- randomness
- noise
- compounding errors



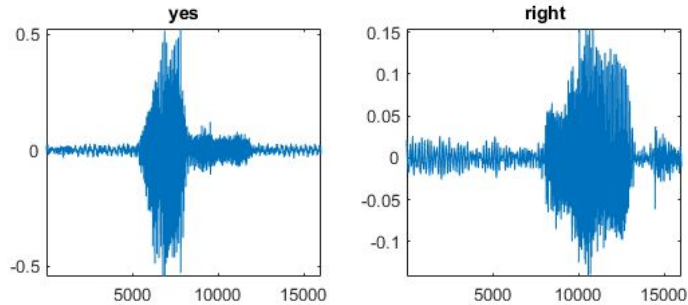
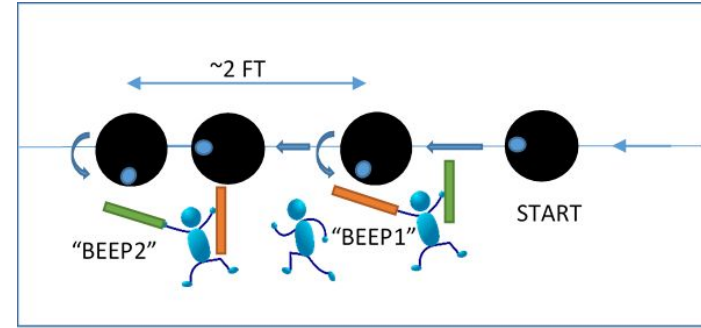
Practice with Functions, Conditionals and Loops

- **for** loops
- **while** loop plus **tic** and **toc** to run on a timer
- while loops & conditionals to check sensors for navigation
- conditionals based on image processing from camera

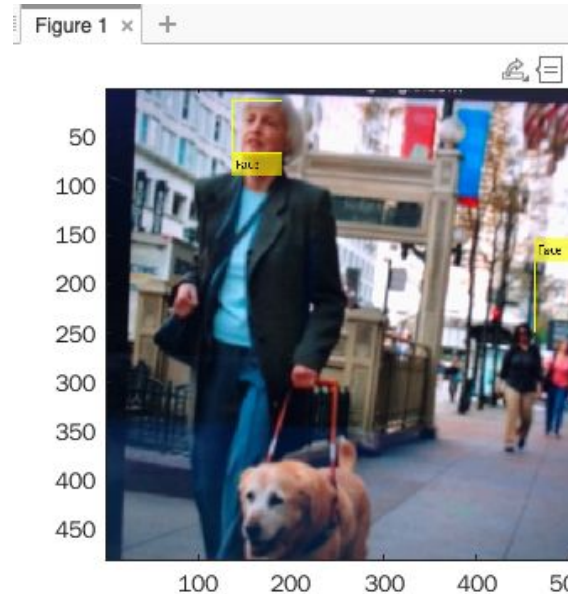
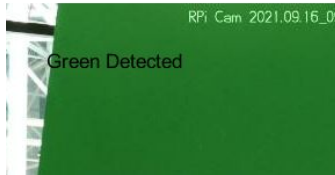


```
gorover.m * +
1  function gorover(rvr)
2  for n=1:4 % repeat 4 times for 4 sides of a square
3      tstart=tic; % notes current time
4      while toc(tstart) < 2 % elapsed time less than 2 secs
5          rvr.SetDriveVelocity(0.8) % set both wheel speeds
6      end % while
7      rvr.stop
8      rvr.turnAngle(90) % turn 90 degs
9  end %for
10 end % go rover
```

Activities and Projects

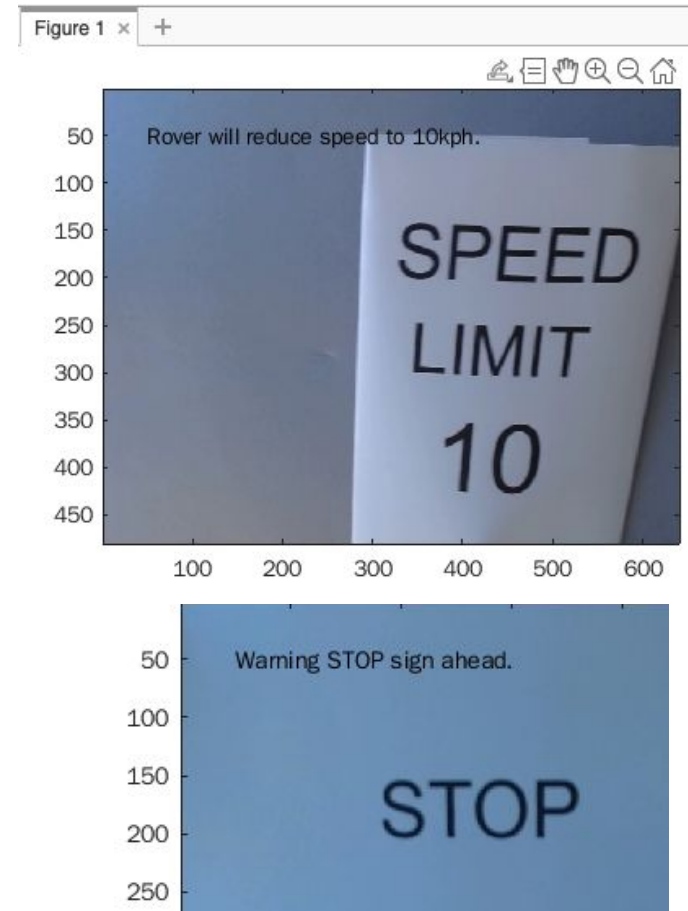


MATLAB's Image Processing

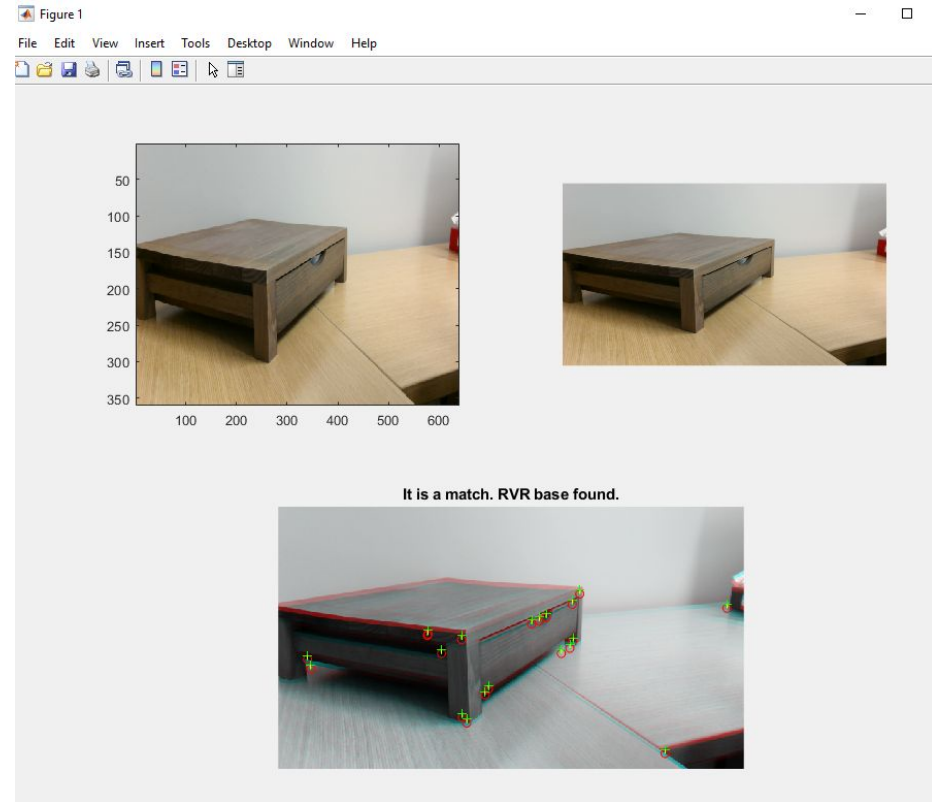
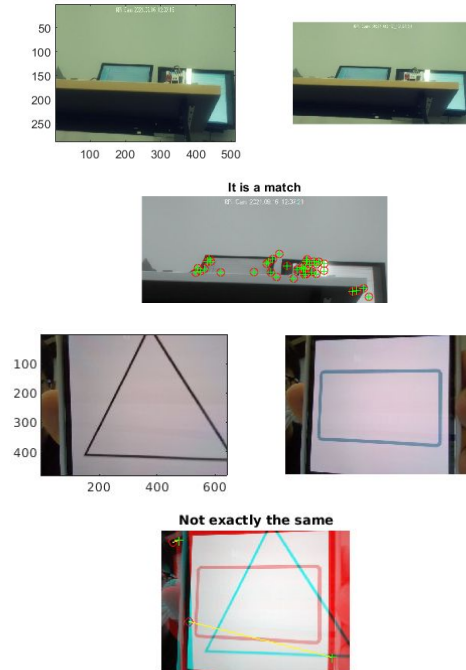


MATLAB's Text Recognition

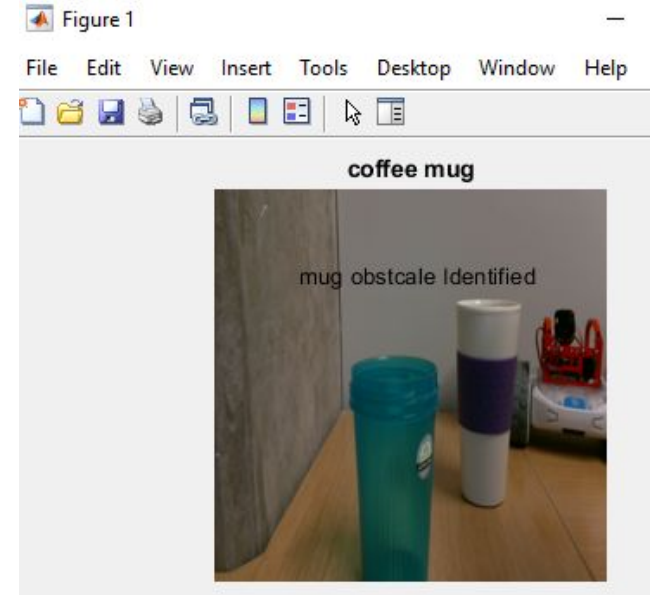
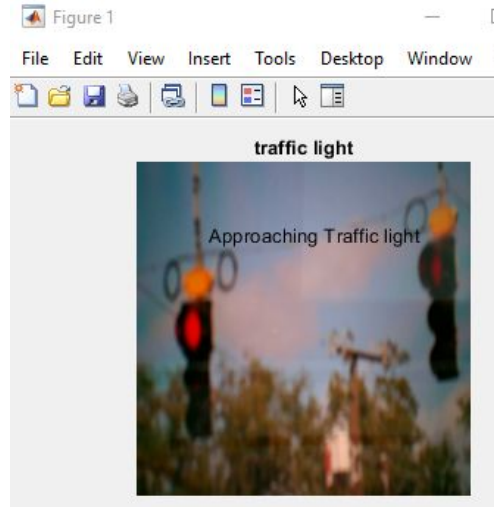
```
RoverPath.txt * x +
1 % check for speed limit signs
2 while true
3     img = rvr.getImage; % get image from RVR
4     p=ocr(img); % optical character recognition
5     image(img) % display camera image in figure window
6     p.Text % display text in command window
7     if contains(p.Text,'LIMIT')
8         if contains(p.Text,'10') % if speed limit 10 detected
9             rvr.setDriveVelocity(10)
10        end
11        pause(1)
12    end
13 end
```



MATLAB's Image Processing: MSER features



MATLAB's Deep Learning Toolbox for AlexNet



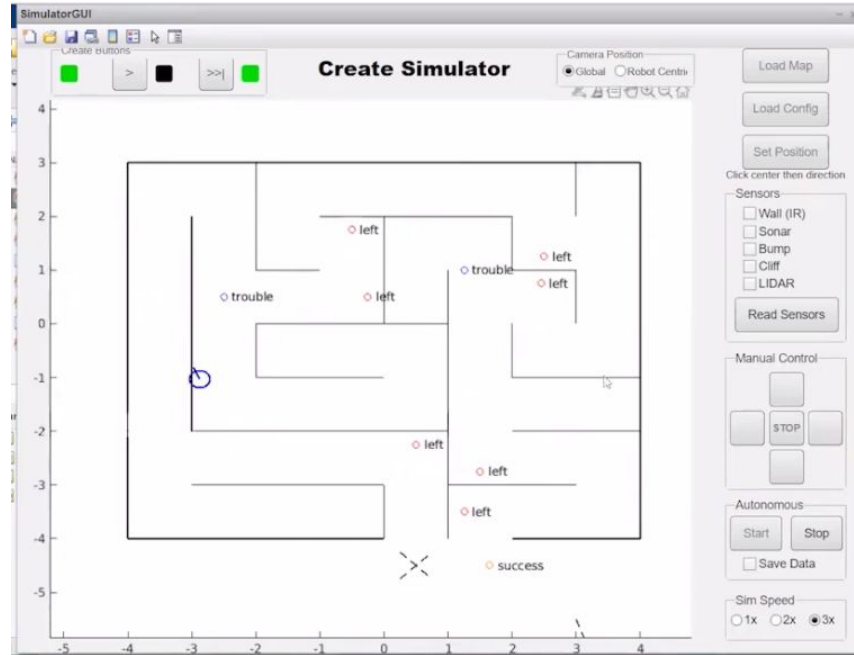
Student Projects use our MATLAB Toolboxes for Raspberry Pi controlled iRobot Create¹ and Sphero RVR



¹ UTK EF Roomba Toolbox is based off the MATLAB toolbox for iRobot Create, developed by Joel M. Esposito, USNA, www.usna.edu/Users/weapsys/esposito/_files/roomba.matlab/

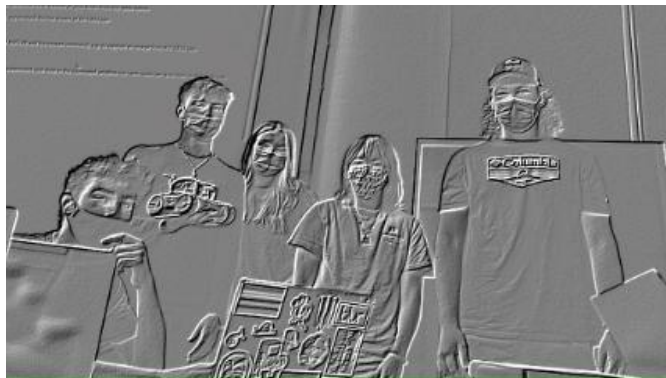
Teaching Online

MATLAB Online
MATLAB Connector
MATLAB Drive
Virtual Create Robots ¹
Webcam, Sound, GUIs



¹ iRobot Create Simulator Toolbox, Copyright 2010 Cornell University. dfan@cs.cornell.edu

Questions?



50
100
150
200
250

100 200 300 400 500

