**Automated Robotic Can Retrieval**

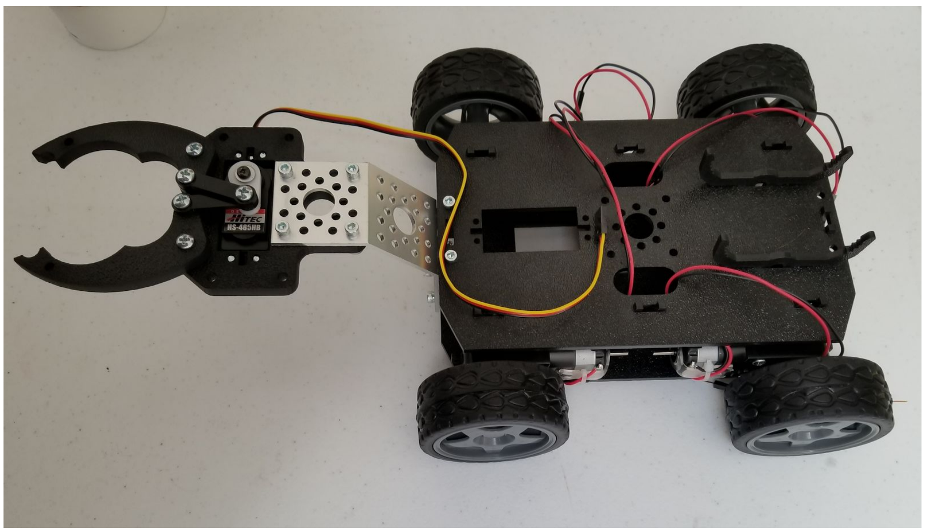
Sam Burkhart,Dakota Ward,Khyati Sinha

ECE 544

Spring 2017

# Initial Proposal

## Design:



Our Team's basic concept is to design an embedded system to explore robot control and design utilizing computer vision and custom IP designs.

Our goal is to create a system that can identify beverage cans, navigate to them, and be able to sort them into distinguishable piles.

Its our aim to develop our application on Digilent's new product: PYNQ-Z1, a board designed to utilize the Xilinx Zynq APSOC and PYNQ, an open-source framework running onboard dual ARM9 CPUs enabling:

- Web server hosting the Jupyter Notebooks design environment :
  This will allow us to use a web browser for displaying plots, telemetry data for demoing and testing our design.
- The IPython kernel and package
- Xilinx Linux Kernel :
  we will use the miniConda, Scikit-learn, and OpenCv packages to develop/implement our design.
- Base hardware library and API for the FPGA

**BOM:**

| **Materials** | **Source** | **Cost** |
|---|---|---|
| PYNQ Board | http://store.digilentinc.com/py | $65 Academic / $229 |

| | | |
|---|---|---|
| | nq-z1-python-productivity-for-zynq/ | Non-Academic |
| Runt Rover Junior | https://www.servocity.com/junior | $27.99 |
| Standard Gripper A | https://www.servocity.com/standard-gripper-kit-a | $9.99 |
| Standard Servo | https://www.servocity.com/hs-485hb-servo | $16.99 - $36.99 |
| 2x Dual H-Bridge Motor Controller PMOD's (DHB1) | http://store.digilentinc.com/pmod-dhb1-dual-h-bridge/ | 2 x $16.99 |
| PYNQ Grove Adapter Shield | http://store.digilentinc.com/pynq-grove-system-add-on-board/ | $9.99 |
| Grove to Female Header Conversion Cable | https://www.amazon.com/Cables-Grove-Female-Jumper-Grove-Conversion/dp/B01CNZ9EEC/ref=sr_1_1?ie=UTF8&qid=1495413461&sr=8-1&keywords=grove+connector | $10.99 |
| 45 degree dual angle bracket | https://www.servocity.com/45-dual-angle-channel-bracket | $1.99 |
| Side Tapped Pattern Mount | https://www.servocity.com/90-quad-hub-mount-c | $5.99 |
| 4 port USB hub | https://www.amazon.com/Inateck-4-port-Ultra-Transfer-MacBook/dp/B01CHYKV9Q/ref=sr_1_11?s=pc&ie=UTF8&qid=1495413973&sr=1-11&keywords=4+port+usb+hub | $8.99 |
| Wifi Dongle | https://www.amazon.com/Rosewill-Wireless-adapter-Dongle-150Mbps/dp/B00ZWPPD0K/ref=sr_1_3?s=pc&ie=UTF8&qid=1495414030&sr=1-3-spons&keywords=wifi+dongle&psc=1 | $7.77 |
| USB WebCam | https://www.amazon.com/Log | $61.99 |

| | | |
|---|---|---|
| | itech-Widescreen-Calling-Recording-Desktop/dp/B006JH8T3S/ref=sr_1_1?s=pc&ie=UTF8&qid=1495414074&sr=1-1&keywords=logitech+c920 | |
| Battery Pack | https://www.adafruit.com/product/1566 | $39.95 |
| Various Nuts and Bolts | ? | ? |

**Mechanical Design:**

The Runt Rover Junior has actobotics connector screw holes on the front and back, allowing for the actobotics side-mount connector plate and 45 degree dual angle pattern bracket to be utilized to attach the actobotics standard gripper A with a servo. This is the right size to grab a standard can. The PYNQ and motors can be driven by a standard cell phone battery pack with the 5V output from the USB charging ports. If additional power is required for the motor's separate from the PYNQ board, a standard AA battery pack will suffice. The camera will be forward facing, mounted using standard ¼" camera mounting bolts to the robot. The PYNQ board will be affixed to the robot with stand-offs. The 4-port USB hub, wifi module, and battery pack will be affixed using velcro mounting tape.

**IP Design:**

The motor controllers will be based on the HB3 controller used for ECE544 Project2/3, extending the IP design for the DHB1 boards. A PYNQ Overlay will be created instantiating 2 DHB1 IP blocks to control 4 motors independently. Another IP block will be used to control the PYNQ arduino grove shield, specifically controlling the gripper arm servo via a PWM grove port. These IP will have C and Python level drivers allowing control from a Jupyter notebook and/or Python script. The camera will be stationary and capture will be controlled using the OpenCV Python library. The logic for can detection and recognition will be developed in Python utilizing OpenCV and SciKit-Learn, with other frameworks under investigation. The motor control and navigation will be designed in Python, with ROS being investigated as well.

## Modules/ Proposed Implementation Goals:

### **Motor Control:(**Sam, **)**

**Peripherals:** Digilent Pmod DHB1

**Basic:**

a) Design an IP block for the Digilent PmodDHB1 to control the motor using open-loop control
b) Instantiate two IP blocks and design a top level robot control module in C/Python.
c) Incorporate manual and automatic robot control hooks for beverage can retrieval and testing.

**Intermediate (stretch):**

a) Design an IP block for the Digilent PmodDHB1 to control the motor using closed-loop control (requires 1 magnet and hall-effect sensor per motor, or 4 total)
b) Create stepper functionality to “step” the motor one revolution at a time.

**Further (stretch):**
a) Design an IP block for the Digilent PmodDHB1 to control the motor using closed-loop control with quadrature encoding (requires 2 magnets and hall-effect sensors per motor, or 8 total)
b) Instantiate two IP blocks and design a top level robot control module in C/Python using Fuzzy Logic control mechanisms and feedback signals.

## **Servo Arm:**(Sam, )

**Peripherals: PYNQ Grove Adapter Shield, Servo, Actobotics Standard Gripper Arm - A**
**Basic:**
a) IP block and Overlay which includes gripper arm control
b) Grab can
c) Release can

**Intermediate (stretch):**
a) Add elevation servo/control
b) Lift can off the ground (grab and elevate)
c) Set the can down (drop and release)

**Further (stretch):**
a) Design a smart arm with several degrees of freedom to sort and move cans without the robot moving
b) Carry multiple cans as payload (requires storage and more complicated arm)

## **Computer Vision:(**Dakota,Khyati **)**

With either the PYNQ board or a Raspberry Pi 3, the Opencv stacked could be leveraged to enable object/feature detection with video/image capture.
Initially, it would be prudent to implement classic CV algorithms to get a basic ability to detect a soda can and have the Robot navigate (find) the can and attempt to pick it up with its grabber claw. I foresee this to not be a trivial undertaking.

For development purposes both Classic CV and Deep Learning implementations will be pursued initially to solve the image processing/ brand name recognition challenge that our design concept requires us to resolve. The idea is for a comparison between the 2 methods and the adoption of the method that will provide the most time-effective.

If a PYNQ board is approved, it would be our preferred platform to house the CV stack and Camera module. Our fallback would be to utilize the RP3 to perform image processing.
**Basic:**
a) Find a (ONE) can using Color detection with Opencv, using the PYNQ webcam interface or an RP3 picam.
   implementation ideas: Convex HULL, using Opencv’s Findcontours(), HOG (histogram of Gradients) detector.
b) Detect a “pile” of cans

c) Feature matching with Opencv: SIFT, SURF, etc. for improved object matching/recognition

**Intermediate:**

a) able to discern between many types(brands) of cans
An example for can soda-can detection would be to use a color/brand name scheme:
green = lemon-lime
blue = pepsi
red = coke
silver = diet coke
brown = root beer

b) use of letter recognition to identify brand names (Alexnet)

**(stretch):** Classic CV implementations have fallen out of favour for the more efficient and performance boosting capabilities that neural networks or Deep Learning constructs afford. A stretch goal would be to to use one of these more advanced and modern application (i.e. multi layered perceptron, neural network,etc) to implement the CV portion of our design. The trade off in performance will be that our system will need training data and our Design schedule will need to set time aside to train, and test our chosen application.

**Brand Label image recognition** using (options):

a) Perceptron (single, multi layered)
b) SVM (support vector Machine)
c) training a DL neural network (Using Alexnet)

## Voice Recognition (Stretch):(Dakota,Khyati )

**Basic(stretch):**

a) add the mic/speakers to the robot for user communication
b) Use existing voice recognition platforms (i.e. Alexa (Amazon), Watson(IBM)) for implementation
c) Command word activates robot navigation towards can pile

**Intermediate (stretch):**

a) Multiple command words recognized
b) Take beverage requests and deliver the correct beverage to the user.

## Demo:

Our initial Idea for the Demo:

1. Robot identifies soda can's of various colors and retrieves it with its grabber claw, sorting them into marked locations.
   The Jupyter notebook framework will allow us to display data (projected to a screen) while our robot is in operation, augmenting our demo with plots/ telemetry data.

**(Stretch)**

2. Robot sorts a pile of different **brand** soda cans into piles per kind and brand.
3. Robot is voice activated and will perform either/both 1 or 2 listed above

## Schedule / Development:

Already Done:

- Robot is assembled with basic gripper and servo installed.
- PYNQ board with battery pack and 4-port USB hub with WIFI dongle and webcam has been assembled and tested.

5/21 -> 5/27:

- Finish assembly of the PYNQ  board to the Robot.
- Implement a WIFI install/connection script to run at boot, and rename the PYNQ hostname to allow use of PDX network for communication/control.
- Create the Overlay and IP for the servo/gripper arm and Pmod DHB1 basic design.
- Create basic telemetry and control for the motors and gripper from a Jupyter notebook.

5/28 -> 6/3:

- Integrate motor controller and gripper controls to the main application and enable manual control.
- Integrate robot controls with image detection and navigation algorithms.
- (stretch) Integrate microphone and speaker for command recognition and verbal feedback.
- Final Progress Report

6/4 -> 6/10:

- Complete integration and plan demonstration
- Demo night on 6/7.
- Project Deliverables due on June 9th at 10pm.