



# BRO

## Basketball Return Optimizer

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## Abstract

In an era where automation is becoming a necessity in almost all facets of life, it is no surprise that the Basketball Return Optimizer's (BRO) main feature is automation via target tracking. Basketball return systems have been developed to help return the basketball to the player after they have made a shot. These return systems are meant to maximize the player's time shooting while limiting the time they have to retrieve the shot basketball. Unfortunately, the player still must manually adjust these systems to control where on the court the ball will be returned. This is an inefficiency that BRO addresses. As it stands, no recreational or professional system can track a player and return the ball to said player no matter where they stand on the court. BRO is a traditional return funnel system that is modified to maximize the players shooting time by using automatic tracking. By taking the funnel, mechanizing it and integrating a webcam that tracks the player, our team has created a system that allows the player to freely move around the court and have the ball returned to them regardless of position.

## System Overview

- Using the SKLZ Shoot Around system, our team made modifications that allow for real time tracking of a single player which allows for the ball to be returned to the player within 8-65 feet.
- The original funnel has a central disc that the unit rotates around. We recreated this disc into a 3D printed gear that is driven by the pinion gear and the motor.
- Frames captured by the webcam are stored in a buffer that are then processed by the BeagleBone.
- An AC Adapter or Battery is used to power the system. On battery power, the player can expect to achieve at least an hour of play time.

## Specifications

| Specification      | Goal              | Actual        |
|--------------------|-------------------|---------------|
| Weight             | < 15lbs           | < 10lbs       |
| Range              | 5-25ft            | 8-65ft        |
| Capture Rate       | >=5 frames/sec    | >5 frames/sec |
| Processing Time    | <=200ms           | Avg. <200ms   |
| Battery Life       | >1 hr.            | >3 hr.        |
| Motor Voltage      | 12V               | 12V           |
| BeagleBone Voltage | 5V                | 5V            |
| Current Draw       | <=3A              | ~1A           |
| RPM                | 45deg/s - 55deg/s | ~50deg/s      |



Figure B: Battery powering the BeagleBone and motor (left) and webcam mounted (right).

## Results

## Block Diagram

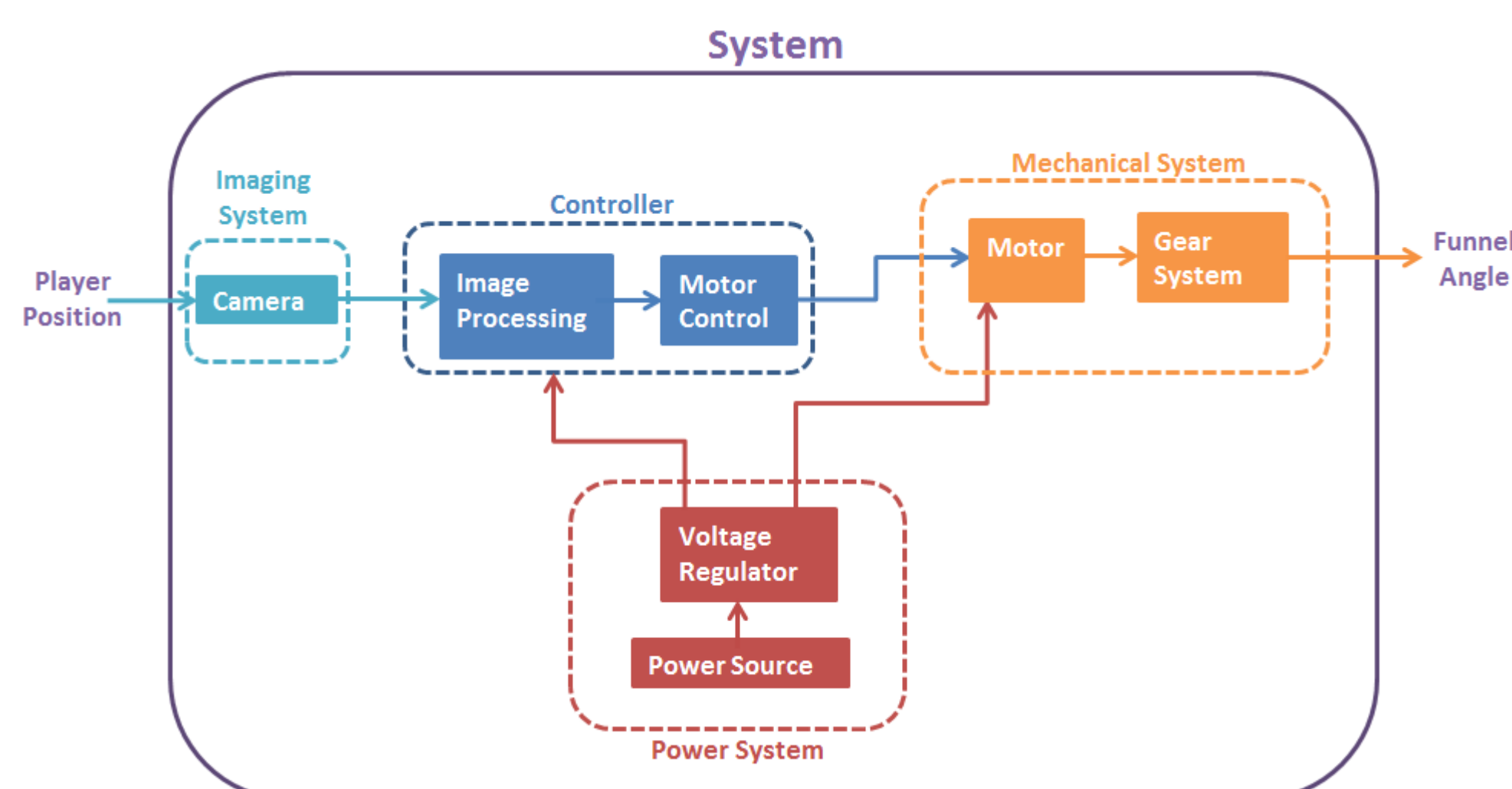


Figure A: Block Diagram featuring four sub-systems.

- Fully functional BRO system
- All specifications that were established from day one were met or exceeded.
- Target detection does not get tricked or affected by the environment due to specified pattern and colors on jersey.
- More effective use of practice time because the player spends less time retrieving the ball.

## Acknowledgement

We want to thank Professor Hossein Pishro-Nik for his tireless support and the professional and personal insight he has provided our team. Acknowledgements also go out to: Joe Howard, MIE Innovation Makerspace, Walmart, M5, Fran, Professors Kelly, Holcomb, Duarte, Soules, Tessier, and Grupen.



Department of Electrical and Computer Engineering

ECE 415/ECE 416 – SENIOR DESIGN PROJECT 2016

College of Engineering - University of Massachusetts Amherst

# SDP16

# Imaging System

- The Logitech C270 Webcam captures images of the player wearing the specified jersey on the court and sends them to the Beaglebone Black for processing.
- The camera has a resolution of 720p which is far greater than we need but gives us flexibility when it comes to looking for the pattern on the jersey.
- The C++ code searches the image for the pattern of red, blue, and green horizontal stripes, and determines which direction the system needs to rotate.

# Controller System

- The BeagleBone Black Rev C is responsible for processing the images taken by the camera and sending them to the mechanical system. The BeagleBone boasts a 1GHz processor and has a Debian Linux operating system.
- To locate the player in the image, the C++ algorithm parses through the pixels looking for the horizontal striped pattern of red, blue, and green. This is called Color Filtering. OpenCV and Video4Linux2 libraries help complete the image processing.
- Once the pattern is located, a signal of either Left, Right, or Center is sent to the H-Bridge which commands the motor to move appropriately.



Figure C: Jersey (left) and sample of image from webcam.

- The code discards certain frames to prevent repeating the same motions from frames taken too close together.
- A grabber thread continuously grabs frames to flush out invalid/repeated frames from the camera buffer while a process thread runs the color filtering detection on valid frames in parallel.

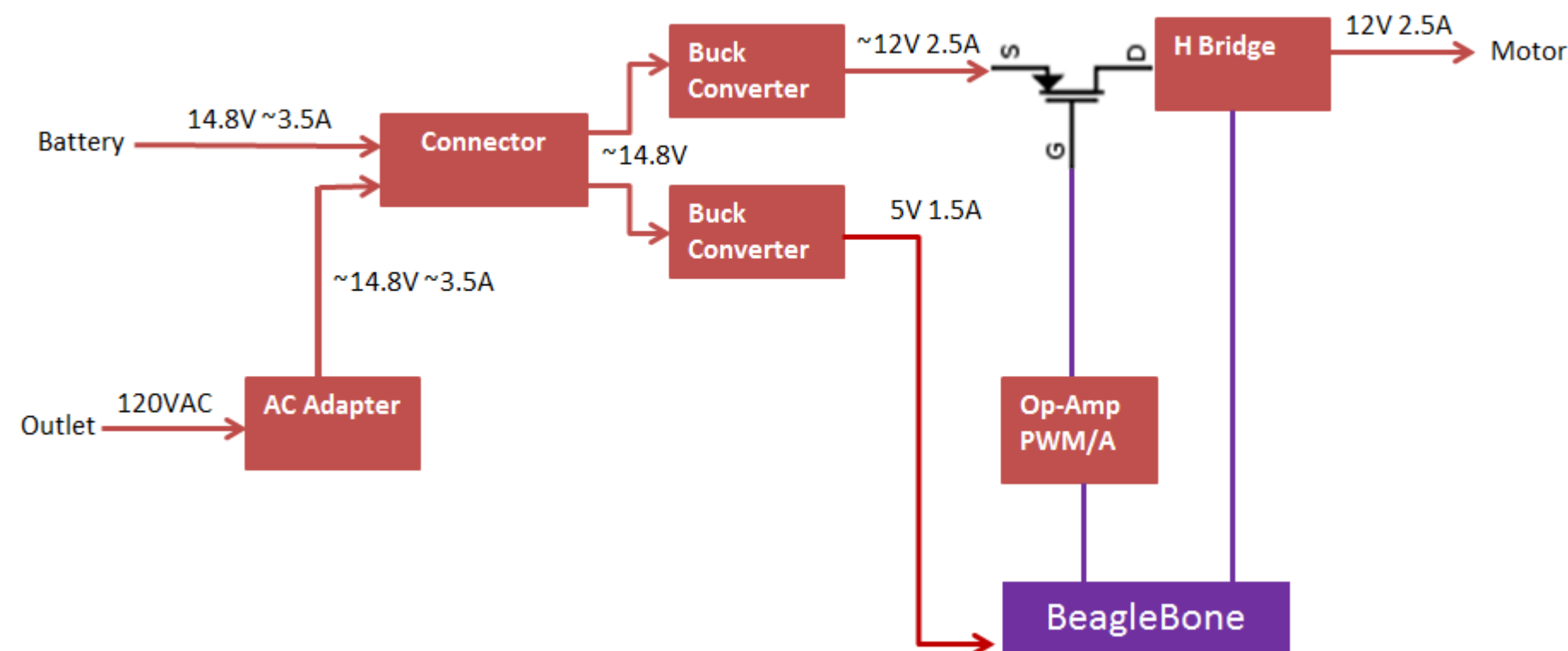


Figure D: Block Diagram for the power system.

# Power System

- The power system consists of the battery / AC adapter and the PCB. The system can run for at least one hour on battery power and for any extended time using the AC Adapter.
- A LIPO battery of 5000mAh is used to power the motor and the BeagleBone.
- Two buck converters are used to regulate the 15V input down to the 12V and 5V needed for the motor and BeagleBone, respectively.
- Motor direction is determined by an H-bridge circuit that takes control signals from the BeagleBone as inputs.

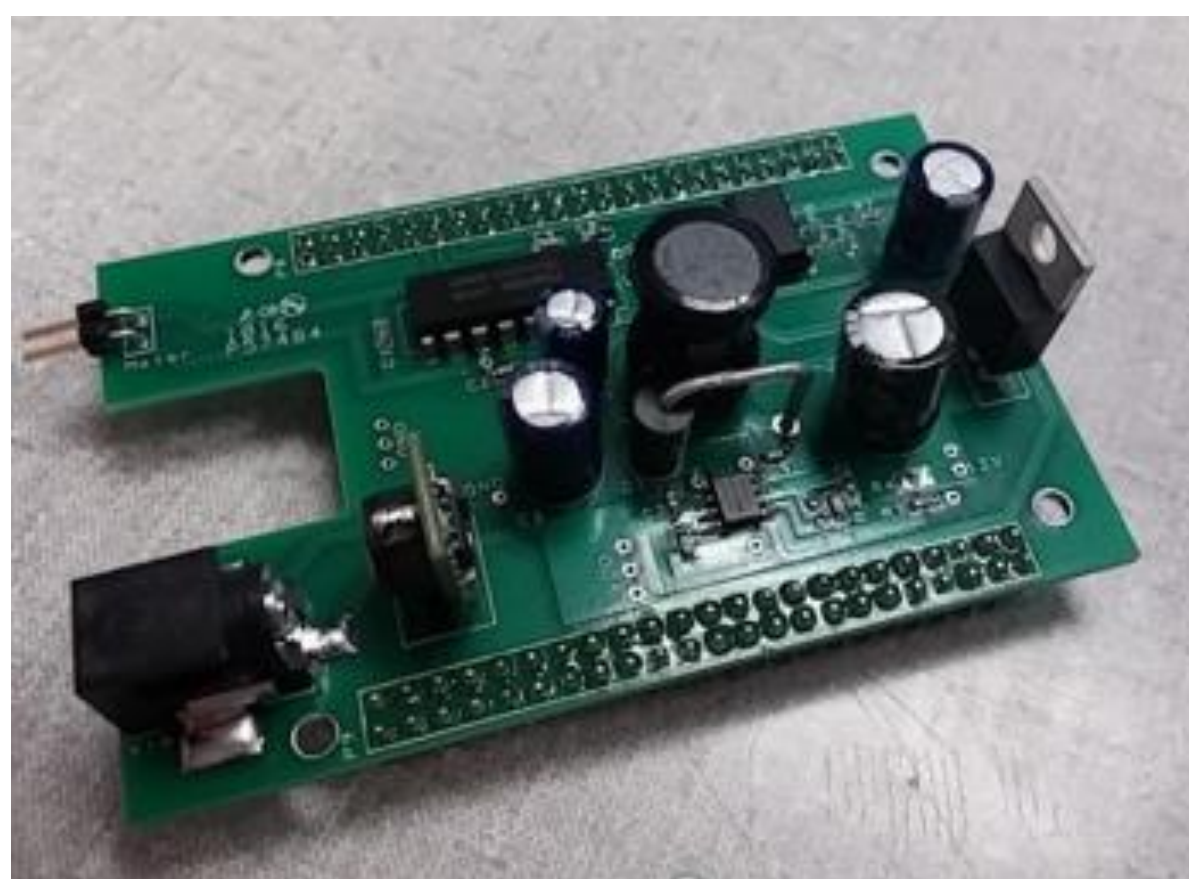


Figure E: PCB shown with motor connection, power port, and pins to connect to BB.

# Mechanical System

## Motor and Gears

- The motor used to rotate the gears is a 60RPM HD Planetary Gear Motor. It offers a very high stall torque and an RPM that is close to the desired RPM.
- A roughly measured minimum torque of 8lbs per inch was calculated to provide one of our requirements for the motor.
- The motor runs on 12V and pulls about 1A under full load.
- The motor drives the pinion gear, which rotates the funnel about the central gear.



Figure F: 3D gears drawn in AutoDesk Inventor

- The pinion gear, attached directly to the motor, is 2 inches in diameter while the bigger gear is 13 inches in diameter.
- The 13 inch gear is modeled after the ring that the SKLZ funnel shipped with. Using AutoDesk Inventor, the ring was built into a 4 piece gear that was melted together with acetone.



Figure G: HD Planetary Motor from servocity.

## Casing and Mounting

- 3D printed cases were built for the Webcam, BeagleBone and PCB, and the Motor. A 3D printed holster was built that will house either the AC Adapter or the Battery.



Figure H: 3D casings mounted to the back of the funnel.

# Cost

| Part                  | Development     | Production (1000) |
|-----------------------|-----------------|-------------------|
| Processor             | \$55.00         | \$13.11           |
| SKLZ Shoot Around     | \$30.00         | \$3.28            |
| PCB                   | \$33.00         | \$5.26            |
| Electrical Components | \$12.14         | \$15.55           |
| Webcam                | \$28.00         | \$28.00           |
| Jersey                | \$20.00         | \$6.09            |
| Battery               | \$40.00         | \$40.00           |
| AC Adapter (optional) | \$13.00         | \$13.00           |
| Motor                 | \$40.00         | \$40.00           |
| 3D Printing           | \$29.74         | \$3.40            |
| Mounting Hardware     | \$8.68          | \$19.65           |
| <b>Total</b>          | <b>\$309.56</b> | <b>\$187.33</b>   |