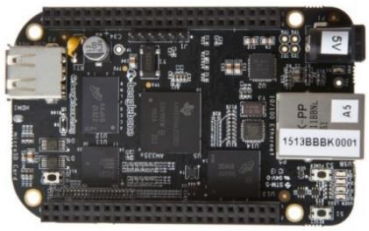
3.1.2 Electrical

3.1.2.1 Microcontroller/Computer

3.1.2.1.1 Raspberry Pi B+ vs. BeagleBone Black

Raspberry Pi B+



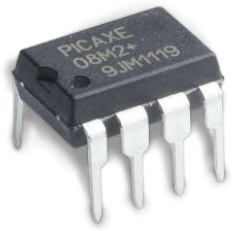
BeagleBone Black

Models	BeagleBone Black	Raspberry Pi
Price	$45	$35
Processor	1 Ghz Ti Sitara AM3359 Cortex A8	700 MHz ARM1176JZFS
RAM	512 MB DDR3L @ 400 MHz	512 MB SDRAM @ 400 MHz
Storage	2 GB on-board eMMC & MicroSD	SD
Video Connections	1 Micro - HDMI	1 HDMI, 1 Composite
Power Draw	210-460 mA @ 5V under varying conditions	150 - 350 mA @ 5V under varying conditions
GPIO Capabilities	65 Pins	8 Pins

Peripherals	1 USB Host, 1 Mini-USB Client, 1 10/100 Mbps Ethernet	2 USB Hosts, 1 Micro-USB Power, 1 10/100 Mbps Ethernet, RPi camera connector

Table 1- Includes both the Raspberry Pi and BeagleBone Black specifications

3.1.2.1.2 PICAXE 08M2



08M2 Specifications	
Memory Capacity (bytes)	2048
RAM (bytes)	128
I/O (bytes)	6
ADC/Touch Pins	3
Max. Freq (MHz)	32
Voltage (V)	5
Current (mA)	20

Table 2 - 08M2 Specifications

3.1.2.1.3 32 I/O Point Expansion & GPIO Shield Board

Figure 1 - MyPi - Protect Your Pi - 32 I/O Point Expansion & GPIO Shield Board

- Increases the Raspberry Pi GPIO pin count from 8 to 32 pins
- Has an added feature to protect the board from damage caused by GPIO inputs.

3.1.2.2 Camera

3.1.2.2.1 Logitech C310 USB 2.0 HD Webcam

Figure 2 - Logitech C310 USB 2.0 HD Webcam

- Linux Compatible
- 5 ft. USB
- Sleek design that can be altered to make waterproof with the addition of epoxy to seal unwanted openings.
- 5MP camera 720 P HD

3.1.2.3 Ultrasonic Ranging Module

3.1.2.3.1

Figure 3 - Ultrasonic Ranging Module

- Voltage DC 5 V , Current 15mA

- Working Frequency 40Hz
- Max Range 4m, Min Range 2 cm
- Measuring Angle 15 degree

3.1.2.5 Motor Control

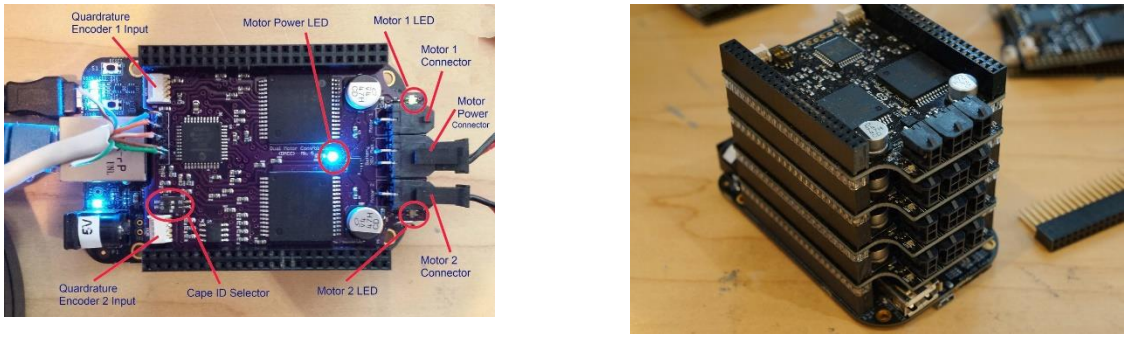


Figure 4 - Dual Motor Controller Cape (DMCC) Mk.6(LEFT), Device can stack to handle up to 8 motors(RIGHT)

- Dual DC motor control (5V to 28V)
- Motor speed and Motor direction (reverse / forward) control
- High Current (up to 7A continuous per motor)
- Stackable, up to 4 DMCCs can be stacked
- Dual Quadrature encoder interfaces on each board
- Built in PID control firmware

Figure 5 - L293D Motor Drive Shield Expansion Board for Arduino which can be interfaced with the Raspberry pi

- This is an Arduino Shield that can be interfaced with the Raspberry Pi B+
- L293D is a monolithic integrated, high voltage, high current, 4-channel driver.
- Can Drive 4 DC motors
- 0.6A average draw with 1.2A peak current

3.1.2.6 Software

3.1.2.6.1 Image Processing Library

- Library of programming functions which are aimed at real-time computer vision

3.1.2.6.2 Kernel

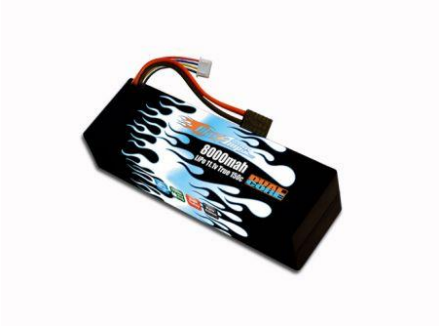
- Open Source operating system which will be used on the Final microprocessor setup

3.1.2.7 Waterproofing Protection

Figure 6 - Waterproof casing Structure

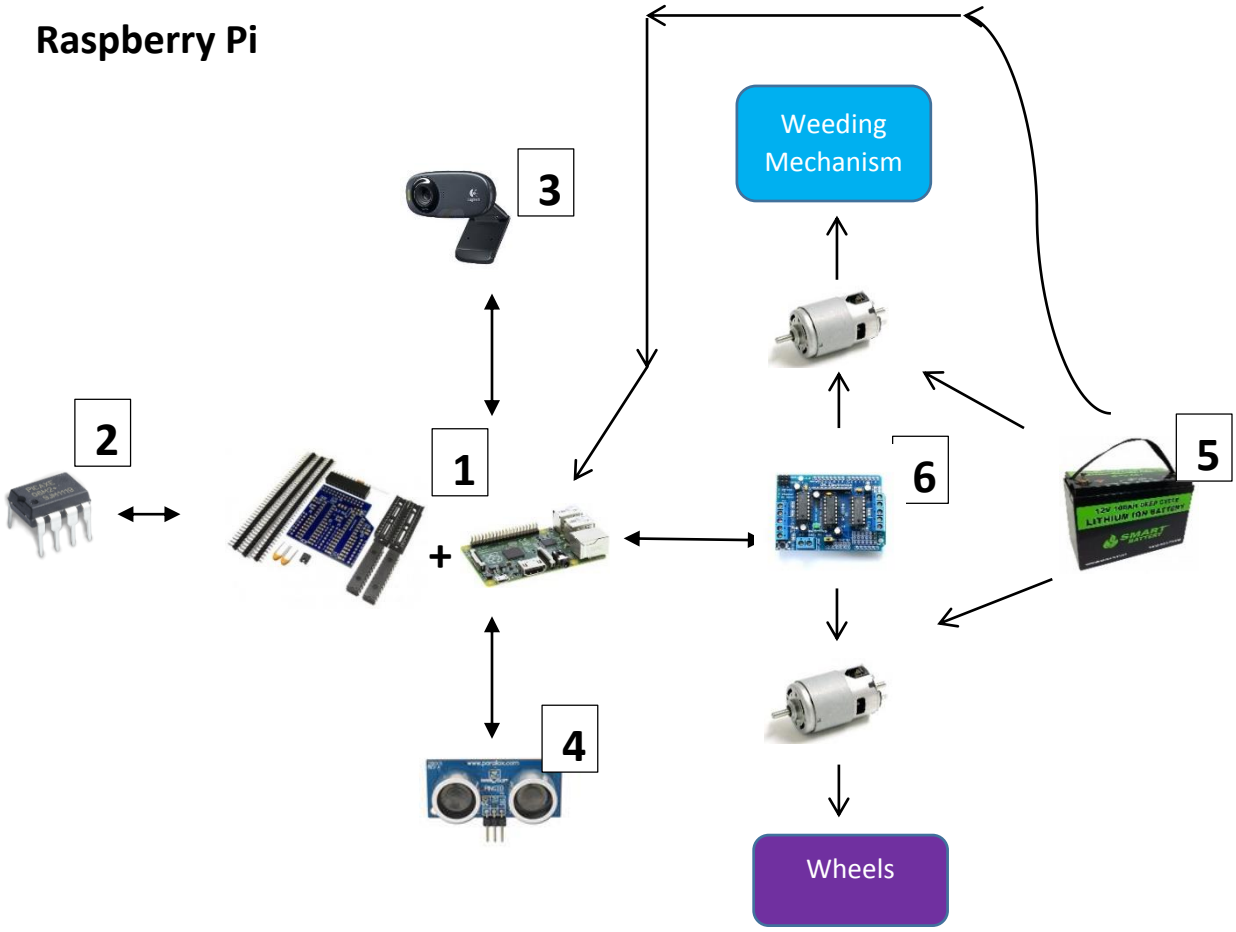
- Air Tight & Waterproof
- Rubber Lining to protect electronic components
- High Strength material used for outer casing to withstand the trials of a life outdoors.
- Dimensions – 9’ x 4.875” x 3”
- Will be modified to attach to the frame of the device. Modifications will also be made to allow for the wires of various peripherals to be handled. All holes will be sealed with high strength epoxy.

3.1.2.8 Battery

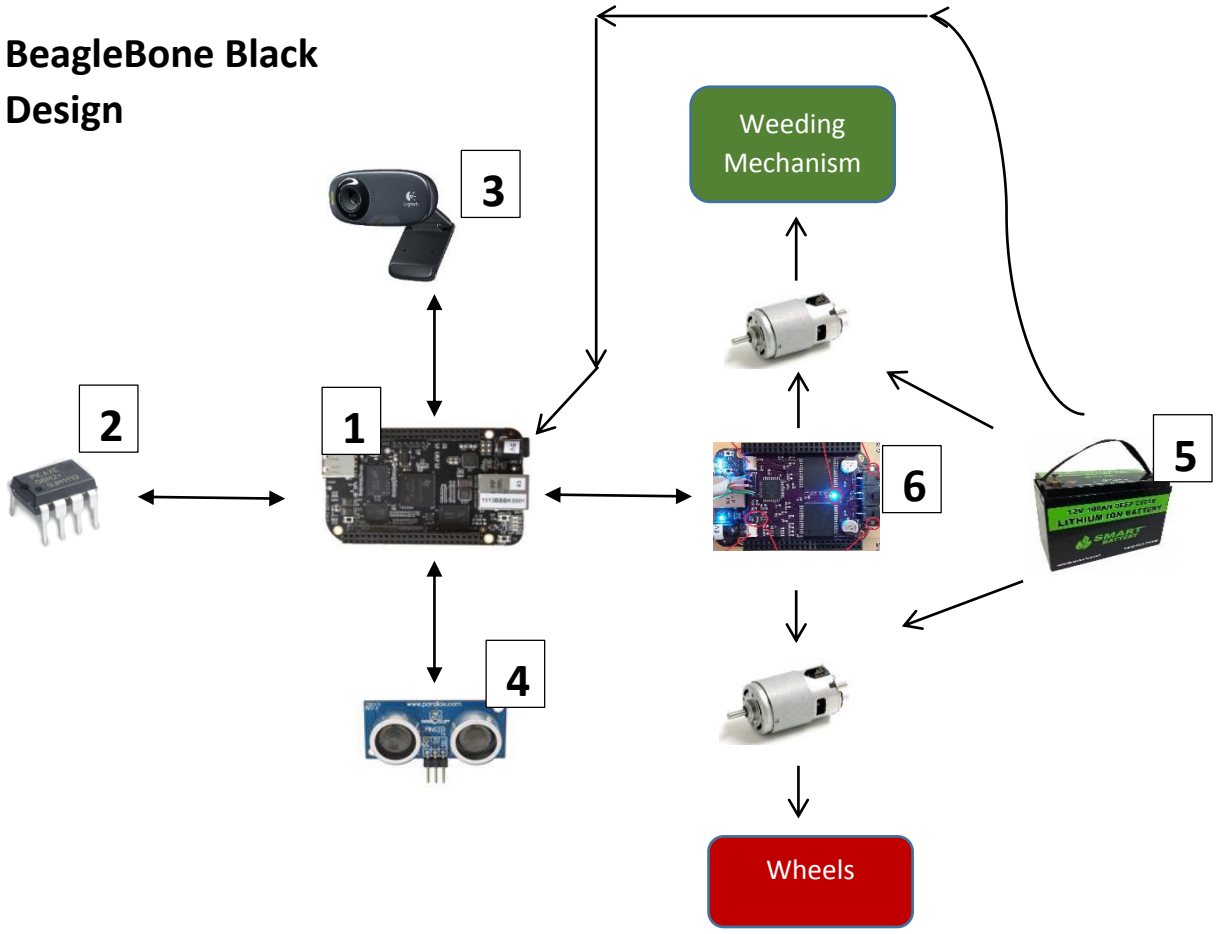


- 11.1V 3 cell battery pack
- 8000mAh capacity
- Hard case and waterproof shell for rugged use outside

3.2 Design Concepts



BeagleBone Black Design



1. Microprocessor (Each Diagram Above has different Controller Setup)
    a. BeagleBone Black – as the main controller for the entire robotic weeder. This device offers a very fast processor coupled with large amounts of memory that will be able to handle the image processing for the camera. This device also has 65 GPIO pins, which is more than enough to handle all the components needed to complete this project.
    b. Raspberry Pi B+ - This device would not be able to control all aspects of the robot by itself, and would require and expansion shield to meet the GPIO pin requirements. The repurposed Arduino shield would give the device 32 GPIO pins.
2. PICAXE 0M82 – A very small microcontroller that can be used to save power and take over control when the robot is in its "stand-by" phase requiring little power which will allow the battery to run longer. Since the Beaglebone runs an operating system it will utilize much needed resources if kept "ON" in the standby phase.
3. Logitech C310 USB 2.0 HD Webcam – This is a small lightweight USB 2.0 webcam that can be customized to make it water resistant. This camera has USB 2.0 interfacing and is

Linux compatible. At 5 MP and 720p at 30 fps this camera is more than adequate to handle the task at hand. Also the camera is equipped with a 5 foot USB cable allowing for easy placement at an elevated position for better field view.

4. Ultrasonic Sensor HC-SR04 Distance Measuring Module – This unit will be used in tandem with the Computer Vision to detect precise distances of objects within the Robotic Weeding bots field of view. Since only one camera will be used to detect the colors of the rows, the Ultrasonic ranging module is a necessity to accurately navigate through the field since you need to cameras for depth perception.
5. 11.1V 8000mAh LiPo Battery – By using 2 LiPo RC battery packs the robot will be able to maintain longer operability times while still being able to power a 4 wheel drive system and the microprocessor. The LiPo hobby batteries are lighter than a larger golf cart or motorcycle battery and will fit the design specifications better.
6. Motor Control
    a. Dual Motor Controller Cape (DMCC) Mk.6 – This motor controller would be more than adequate to deal with as many motors as needed. This device also excels in the fact that it can handle motors with high peak currents up to 7 A.
    b. Durable Motor Drive Shield Expansion Board L293D – This motor controller would be able to handle the amount of motors needed to complete the project. This device lacks in its ability to handle higher power motors. Also the interfacing of this device would be complicated.

3.2.1 Design Cost Estimate

Raspberry Pi B+ Design		
Item	**Quantity**	**Cost**
Raspberry Pi B+	1	$38.44
Logitech C310 USB 2.0 HD WebCam	1	$49.99
Durable Motor Drive Shield Expansion Board L293D	1	$6.24
PICAXE-08M2 microcontroller	1	$1.89
SainSmart HC-SR04 Ranging Detector Mod Distance Sensor (Blue)	1	$8.42
1450-00 Small Polycarbonate Waterproof Case	1	$14.99
11.1V 8000mAh LiPo Battery	2	$379.98
Sum		$499.95

BeagleBone Black Design		
Item	**Quantity**	**Cost**
BeagleBone Black	1	$52.95
Logitech C310 USB 2.0 HD WebCam	1	$49.99
Dual Motor Controller Cape (DMCC) Mk.6	2	$136.00
PICAXE-08M2 microcontroller	1	$1.89
SainSmart HC-SR04 Ranging Detector Mod Distance Sensor (Blue)	1	$8.42
1450-00 Small Polycarbonate Waterproof Case	1	$14.99
11.1V 8000mAh LiPo Battery	2	$379.98
Sum		$644.22

3.2.2 Power Analysis of control system

Power Analysis of Designs		
	BeagleBone Black Design	**Raspberry Pi B+**
Current (mA)	460	350
Voltage (V)	5	5
Power (W)	2.3	1.75

All the electronic devices will be run off the chosen microprocessor, making the power analysis based off the maximum power usage of the given microprocessor.

3.3 Evaluation of Designs

	Cost	Power Consumption	Board Connections	Microprocessor Speed	Microprocessor Architecture	Shield Expandability	Setup Difficulty	Total Score
Raspberry Pi Design	5	5	2	3	3	4	3	25
BeagleBone Black Design	4	4	5	5	5	3	5	31

Table 3 - Decision Matrix For final Design (1 being WORST & 5 being BEST)

3.3.1 Criteria/Method

The main difference between these two concepts is the microprocessor at the center of each design. The first design uses the BeagleBone black microprocessor from TI, whereas the second design uses the Raspberry Pi microprocessor board. In order to pick between these two designs, we used a decision matrix to compare certain aspects of each design. The Raspberry Pi is a simpler board than the BeagleBone, which is slightly cheaper and consumers less power. Although this is a difference, it is not a huge difference because both microprocessors are relatively cheap and consume at max less than 500mA at 5V.

The first major difference between the boards is the amount of GPIO pins on the board itself. The BeagleBone has 65 and the Raspberry Pi only has 8. This is a huge factor in the project because the board will need to interface with multiple sensors and a motor controller, so even though the Raspberry Pi could accomplish this, the BeagleBone has a large advantage.

Another huge difference between the boards is the processor on the microprocessor boards. The Raspberry Pi uses and older ARM architecture which is not supported by newer Linux distributions, and runs at a slower clock rate of 700MHz. The BeagleBone runs on a more modern ARM 8 architecture, which is supported by newer Linux distributions, at a clock rate of 1 GHz. Since the Microprocessors will be used for Real-Time DSP, the faster processor will be able to process more frames per seconds giving a more up to date and accurate data to the robot.

The final part of the decision matrix is the setup and expandability of the microprocessor boards. Since the Raspberry Pi is a slightly more accessible board and has been out for longer, there are more shields and attachments. It is also able to interface with a number of Arduino microcontroller shields, which the BeagleBone cannot. However since the

BeagleBone has more GPIO pins, this is not a huge concern. The final consideration was the ease of setup and use of the microprocessor boards. The Raspberry Pi does not come loaded with an operating system and requires a separate monitor for display when programming. The BeagleBone Black comes pre-installed with an operating system, and a console window can be brought up through a regular desktop window through a USB connection. It also has onboard memory instead of using an SD card.

3.3.2 Selection of Optimum ones

Based on research and much deliberation the final design for the Robotic Weeding Device will be based off the *BeagleBone Black*. This setup ranked high on the decision matrix based on the ease of use, speed of the processor, number of GPIO pins, and the microprocessor architecture. These factors outweighed the fact the Raspberry Pi design was cheaper.

Final Control System Design: BeagleBone Black Design