UCI Rescue Robotics

2016-2017

Ground Robot Manual

I. CHANGES FROM 2014-2016

- Android with Eclipse is no longer supported with recent IOIO libraries. Consider switching to Android Studio
- A new IOIO library (5.06/5.05) has been released as a release candidate. Use this version or 5.00/5.04.
- Some Bluetooth dongles may not work with the IOIO. Dongles listed at https://github.com/ytai/ioio/wiki/Supported-Bluetooth-Dongles will work for certain.

II. DO'S AND DON'TS

Do not:

- Block/hold the motors or servos when they are running/turning. This will damage the motors/servos and the electronics.
- Control the robot to move from full speed in one direction to full speed in the other. This will damage the motors and the electronics.

Do:

- Check the max (peak, stall...) current and operating voltage for each electronic device you use.
- Check all the wire connections before plugging the battery and powering the robot

III. PREREQUISITE

Participants should have:

- Computer/laptop (Windows or Mac preferred)
- Android phone (with Android > 2.2 preferred)
- USB cable to connect phone to laptop

Participants should have downloaded on their computer:

1. Android SDK (Android Studio, no longer Eclipse)
   (http://developer.android.com/sdk/index.html)

2. All the Android tools and Android APIs (e.g. Android 4.4.2…). This might take a couple of hours
   Some packages might not get installed but that's ok.
   (http://developer.android.com/sdk/installing/adding-packages.html)

3. The latest IOIO libraries (Client Software, 5.06/5.05: App-IOIO0505.zip)
   https://github.com/ytai/ioio/wiki/Downloads

IV. PARTS

1. **Dagu Wild Thumper 6WD All-Terrain Chassis, Black, 75:1, (QTY: 1)**

   This rugged, 6-wheel-drive chassis from Dagu Electronics is designed to excel at traversing rough terrain and steep inclines, making it a great platform for any robot that needs to perform tasks in a complex outdoor environment. It features **six powerful DC motors with brass brushes and 75:1 steel gearboxes** and a unique "super-twist" suspension system acts to keep each wheel in contact with the ground for maximum traction, even when driving over uneven or bumpy surfaces. The suspension can be adjusted to suit different loads and conditions.

   The chassis' aluminum plate has 4mm holes spaced every 10mm, providing plenty of options when it comes to mounting your control electronics, sensors, and additional hardware, and with a maximum recommended **payload of 5 kg (11 lb).** This is a differential-drive chassis, meaning that turning is accomplished by driving the motors on the two sides of the platform at different speeds. The three motors on each side of the robot are wired in parallel, so **only two channels of motor control are required** to get this chassis moving. The motors are intended for a maximum nominal operating voltage of 7.2 V (2V minimum), and each has a **stall current of 6.6 A** and a no-load current of 420 mA at 7.2 V.

   Note: the motors will briefly draw the full stall current when abruptly starting from rest (and nearly twice the stall current when abruptly going from full speed in one direction to full speed in the other…**SO DO NOT DO THIS! The max current would be 6.6A x 2 x 3motors = 39.6A per channel**). Controlling the robot this way would damage the motors and the electronic components.

http://www.pololu.com/product/1563

2. **Motor controller RoboClaw 2x30A, (QTY: 1)**

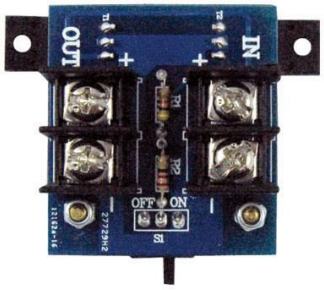
   The RoboClaw motor controllers from Orion Robotics can control a pair of brushed DC motors using USB serial, TTL serial, RC, or analog inputs. Integrated dual quadrature decoders make it easy to create a closed-loop speed control system. **This version can supply a continuous 30 A per channel (60 A peak)**.

https://www.pololu.com/product/3286

3. **Switches**

   a. **Wild Thumper High Power Switch, (QTY: 1)**

   Battery voltage: 6V -20V
   Current rating: 10A continuous - No heatsink
   Current rating: 30A continuous - Chassis used as heatsink with heat transfer compound.
   Current rating: 60A continuous - Heavy duty heatsink, fan and heat transfer compound.



https://robosavvy.com/store/dagu-wild-thumper-high-power-switch.html

   b. **Illuminated Toggle Switch On / Off (Red), (QTY: 1)**

   Toggle Switch and Cover - Illuminated (Red), rated for 12V 20A, includes Missile Switch Cover.

http://www.robotshop.com/en/illuminated-toggle-switch-red.html

4. **Duratrax NiMH Onyx 7.2V 5000mAh Stick Standard Plug, (QTY: 2)**

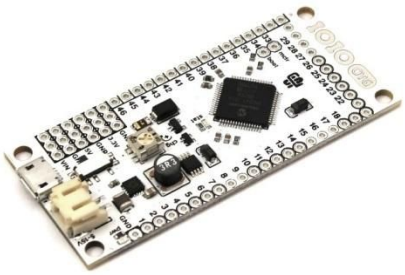
http://www.amazon.com/Duratrax-NiMH-5000mAh-Stick-Standard/dp/B004AF88K0/ref=sr_1_cc_1?s=aps&ie=UTF8&qid=1414970891&sr=1-1-catcorr&keywords=DuraTrax+NiMH+Onyx+7.2V+5000mAh

5. **Duratrax Onyx 200 AC/DC Sport Peak Charger, (QTY: 1)**

http://www.amazon.com/Duratrax-Onyx-Sport-Peak-Charger/dp/B001BCF4YS/ref=sr_1_1?s=toys-and-games&ie=UTF8&qid=1414971105&sr=1-1&keywords=DuraTrax+Onyx+200

6. **IOIO-OTG, (QTY: 1)**

   Are you a Java developer looking to add advanced hardware I/O capabilities to your Android or PC application? Well then the IOIO-OTG is for you! The IOIO-OTG (pronounced “yo-yo-O-T-G”) is a development board specially designed to do just that. It features a PIC microcontroller which acts like a bridge that connects an app on your PC or Android device to low-level peripherals like GPIO, PWM, ADC, I2C, SPI, and UART. An app-level library helps you write control code for these low level peripherals in the same way you’d write any other Java app! The IOIO-OTG has two on-board voltage regulators: a switching regulator that can take 5V-15V input and outputs up to 3A of stable 5V, a linear regulator that feeds off the 5V line and outputs up to 500mA of stable 3.3V



https://www.sparkfun.com/products/13613

7. **Arduino MEGA ADK R3, (QTY: 1)**

   The Arduino ADK is a microcontroller board based on the ATmega2560 (datasheet). It has a USB host interface to connect with Android based phones, based on the MAX3421e IC. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. The ADK is based on the Mega 2560. Similar to the Mega 2560 and Uno, it features an Atmega8U2 programmed as a USB-to-serial converter.

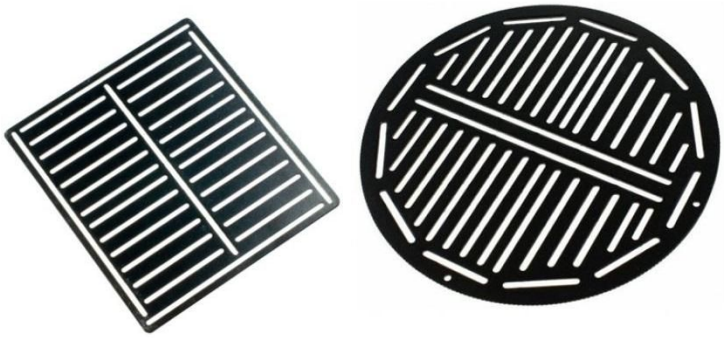
http://www.amazon.com/Arduino-MEGA-ADK-R3-Android/dp/B007BT37BC

8. **Satechi USB 4.0 Bluetooth Adapter, (QTY: 1)**

http://www.amazon.com/Satechi-Bluetooth-Adapter-Windows-compatible/dp/B008BC1U4O/ref=sr_1_3?s=electronics&ie=UTF8&qid=1414969497&sr=1-3&keywords=bluetooth+dongle

9. **Prototyping plate: DFRobot 17cm x 15cm Prototyping Plate or DFRobot 2WD Mobile Platform Expansion Plate, (QTY: 1)**

   Includes: M3 screw set (30 units), M3 * 10 Hexagonal Copper standoffs (10 units), M3 * 20 Hexagonal Nylon standoffs (10 units), M3 * 50 Hexagonal Nylon standoffs (10 units)



http://www.robotshop.com/en/dfrobot-prototyping-plate.html
http://www.robotshop.com/en/dfrobot-2wd-expansion-plate.html

10. MaxSonar EZ0 Ultrasonic Range Finder, (QTY: 4)

The LV MaxSonar EZ0 offers very short to long-range detection and ranging, in an incredibly small package with ultra low power consumption. The LV MaxSonar EZ0 detects objects from 0-inches to 254-inches (6.45-meters) and provides sonar range information from 6-inches out to 254-inches with 1-inch resolution. Objects between 0-inches and 6-inches range as 6-inches. The interface output formats included are pulse width output, analog voltage output, and asynchronous serial digital output. The EZ0 offers the most sensitivity of the MaxSonar Product line, yielding a controlled wide beam with high sensitivity.

http://www.superdroidrobots.com/shop/item.aspx/lv-maxsonar-ez0-ultrasonic-range-finder/830/

11. Single MaxBotix Sonar Servo Arm Bracket, (QTY: 4)

http://www.superdroidrobots.com/shop/item.aspx/single-maxbotix-sonar-servo-arm-bracket/1644/

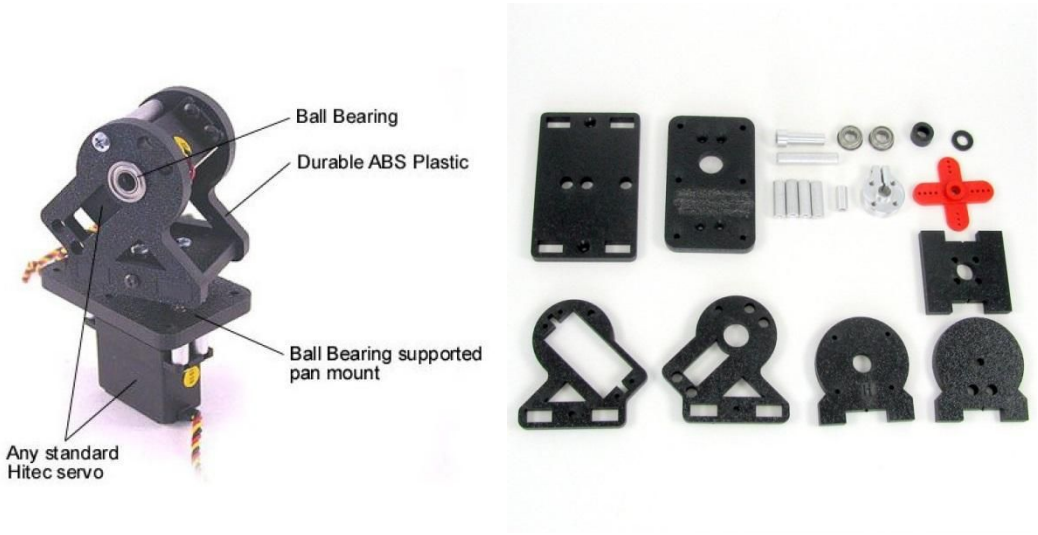
12. HS-485HB Servo, (QTY: 2)

- Speed (sec/60o): 0.20(4.8V), 0.17(6V)
- Torque (Kg-cm/Oz-in): 5.2/72(4.8V), 6.4/89(6V)
- Size (mm): 39.9 x 19.8 x 37.9
- Weight: 45 g / 1.59 oz

http://www.robotshop.com/en/hitec-hs-485hb-servo-motor.html

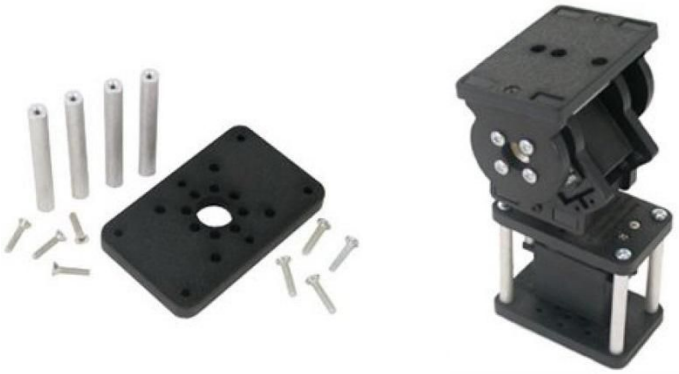
13. SPT200 Direct Drive Pan & Tilt System, (QTY: 1)

Can use any standard size Hitec servo. Perfect for cameras or sensors up to 2 lbs.



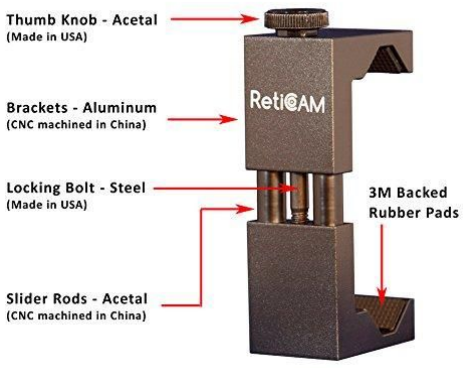
http://www.robotshop.com/en/servocity-spt200-pan-tilt.html

14. Direct Drive Pan Base Mount for SPT200, (QTY: 1)



http://www.robotshop.com/en/direct-drive-pan-base-mount-spt200-or-ddp125.html

15. RetiCAM® Smartphone Tripod Mount, (QTY: 1)



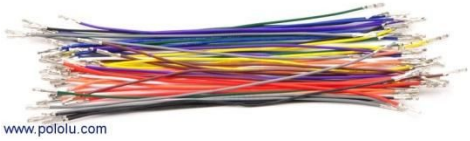
http://www.amazon.com/RetiCAM%C2%AE-Smartphone-Tripod-Mount-Universal/dp/B00FS5L9D4/

16. Wires/connectors (22AWG circuit, 14AWG power/motors)

a. **Wires with Pre-crimped Terminals 50-Piece Rainbow Assortment Female-Female 6", (QTY: 1)**

http://www.pololu.com/product/1800

b. **Wires with Pre-crimped Terminals 50-Piece Rainbow Assortment Male-Female 6", (QTY: 1)**



http://www.pololu.com/product/1801

c. **Stranded Wire: White, Black, Red, 22 AWG, 50 Feet, (QTY: 1 each color)**

http://www.pololu.com/product/2649
http://www.pololu.com/product/2640
http://www.pololu.com/product/2642

d. **0.100" (2.54 mm) Breakaway Male Header: 1x40-Pin, Straight, (QTY: 2)**

http://www.pololu.com/product/965

e. **0.1" (2.54mm) Crimp Connector Housing: 1x1-Pin 25-Pack, (QTY: 4)**

http://www.pololu.com/product/1900

f. Female Crimp Pins for 0.1" Housings 100-Pack, (QTY: 1)

http://www.pololu.com/product/1930

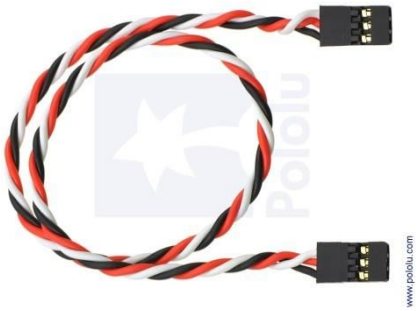
g. JR Connector Pack, Male, (QTY: 4)

http://www.pololu.com/product/1925

h. JR Connector Pack, Female, (QTY: 4)

http://www.pololu.com/product/1924

i. Twisted Servo Extension Cable 12" Female - Female, (QTY: 2)



http://www.pololu.com/product/2166

j. Twisted Servo Extension Cable 12" Male - Female, (QTY: 7)

http://www.pololu.com/product/2169

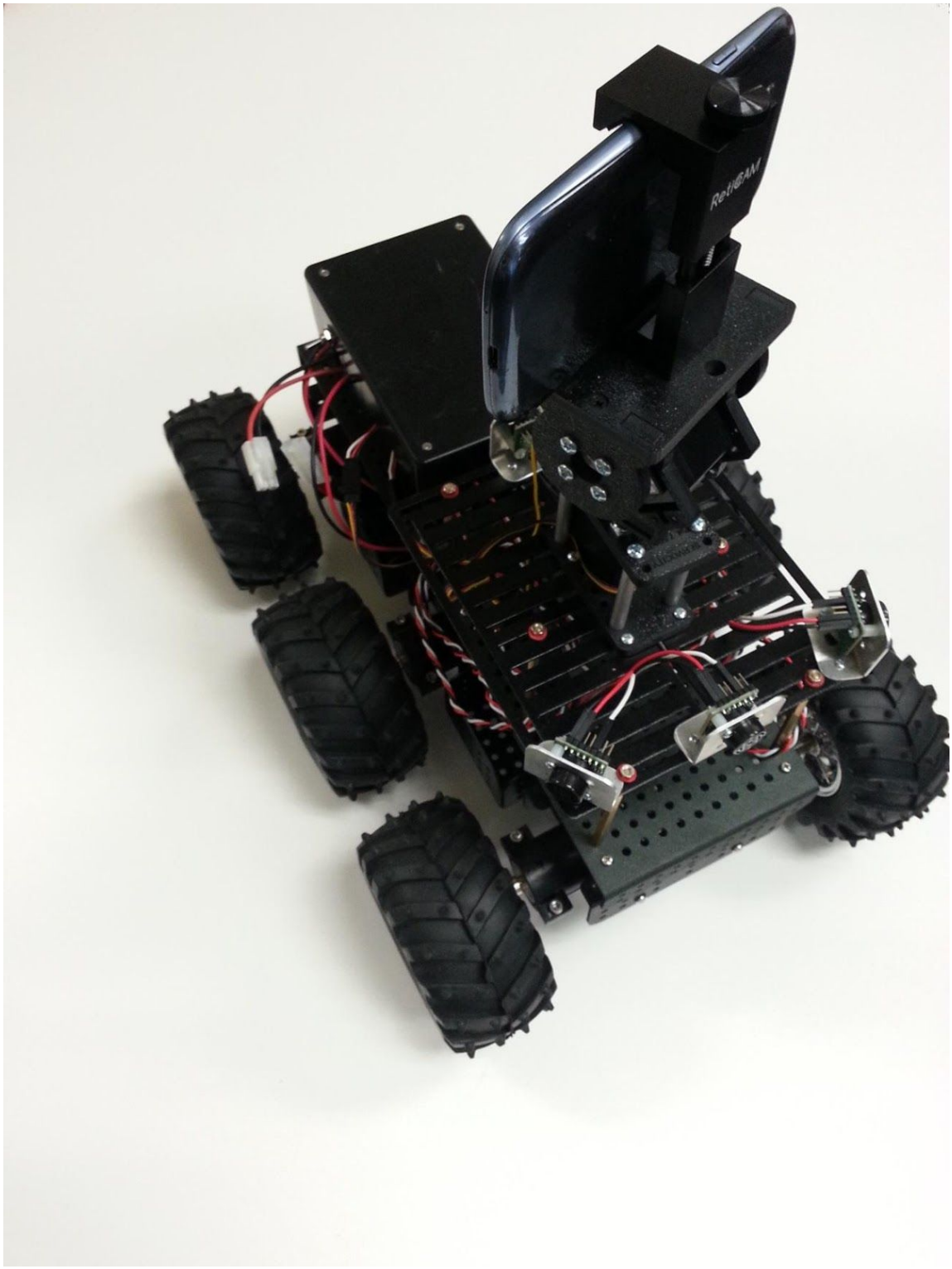
k. Grand General Red, Black, 14-Gauge Primary Wire, (QTY: 1 each color)

http://www.amazon.com/Grand-General-55241-14-Gauge-Primary/dp/B00INVEUP4/ref=pd_bxgy_auto_text_y
http://www.amazon.com/Grand-General-55240-14-Gauge-Primary/dp/B00INVEUNQ/ref=pd_bxgy_auto_text_y

l. Tamiya Plug with 10cm Leads, Female, 14AWG (QTY: 2)

http://www.pololu.com/product/2172

V. GENERAL DESIGN



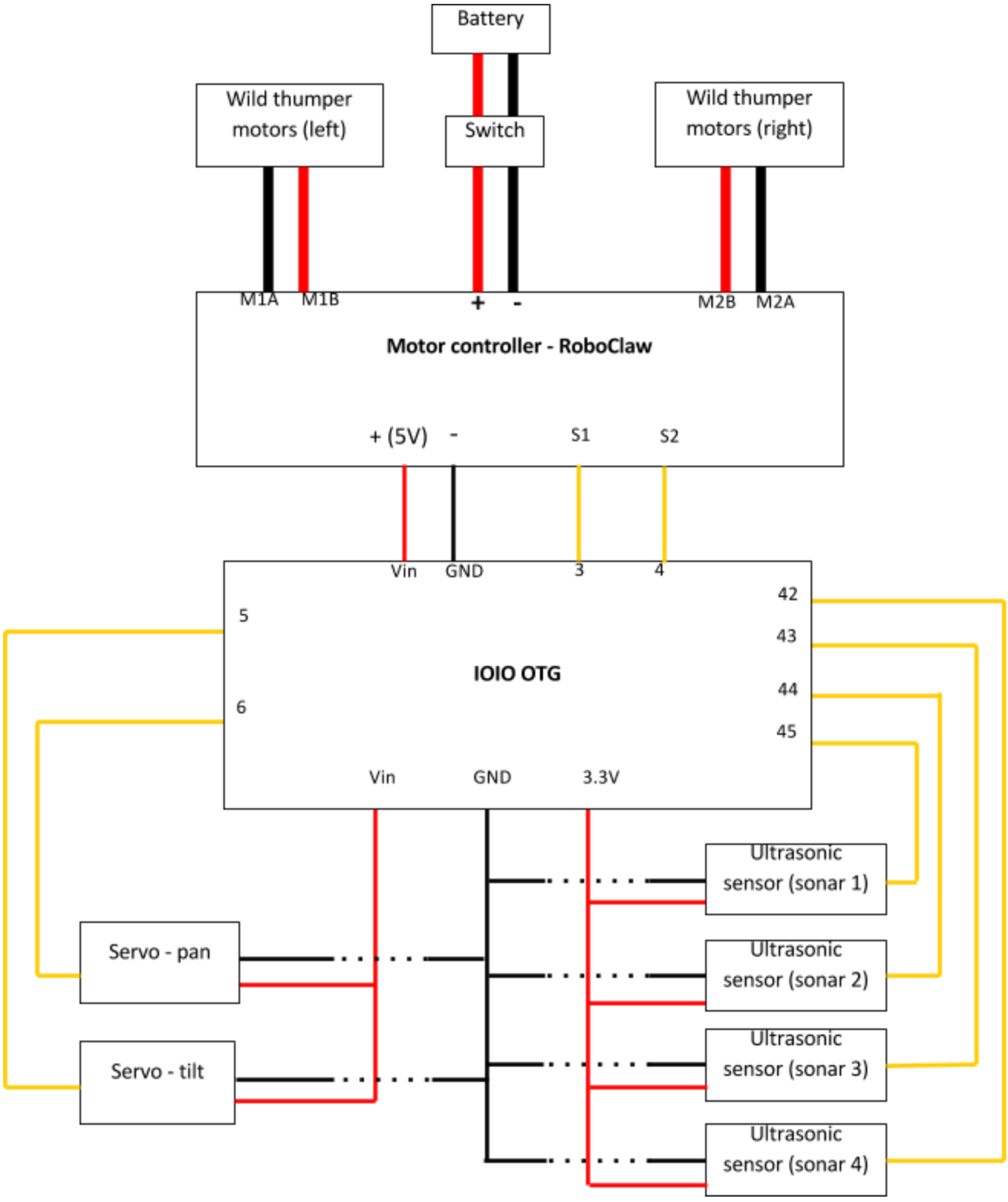


Figure 1. Possible setup of the different components of the ground robot. Schematic not drawn to scale. Thick lines are 14AWG

wires, thin lines are 22AWG wires.

1. Power supply

The battery is connected to the switch using the Tamiya Plug, in order to provide power to the motor controller (+ -). Use 14 AWG wires to connect the switch to the RoboClaw motor controller. Multiple batteries can be wired in parallel for higher autonomy.

The left and right motors are connected to the screw terminals (M1A, M1B, M2A, M2B). Use 14 AWG wires to connect motors to motor controller.

The motor controller can provide power (5V/3A) to the IOIO and servos, using its internal BEC and its encoder power pins. You need to make sure the jumper is on LB-MB (see documentation RoboClaw motor controller).

On the motor controller, the positive encoder power pin (+) is located at the board edge and supplies +5VDC. The ground (-) pin is near the heatsink. The + pin is connected to *Vin* on the IOIO, and the – pin is connected to a ground (*GND*) pin on the IOIO. Use 22 AWG wires to connect the IOIO to the motor controller.

The servos of the pan and tilt unit are also powered directly from the motor controller. This can be done by connecting the black wire of a servo to a *GND* pin on the IOIO, and the red wire of a servo to a *Vin* pin of the IOIO (therefore the IOIO and the servos will be powered in parallel).

The sonars are powered by 3.3V generated by the IOIO. There are only three 3.3V pins on the IOIO so you will need a Y connector to power two sonars in parallel from 1 pin. Connect the 3.3V of the IOIO to the +5 pin on the sonars (accepts 2.5V to 5.5V), and the GND pin to the GND pin.

If necessary, you can power the motor controller and the IOIO separately using two batteries (method not described here).

2. Controlling the motors

They are different ways to control the motors (see documentation motor controller). The simplest way is to send PWM signals to the motor controller I/O pins S1 and S2. The motor controller has to be set on RC mode or RC mode with mixing (see documentation to change mode). In RC mode, S1 controls the direction and speed of motor 1 and S2 controls the speed and direction of motor 2. This drive method is similar to how a tank is controlled. In RC mode with mixing, S1 controls speed and direction of both motors 1 and 2. S2 controls steering by slowing one of the motors. This drive method is similar to how a car would be controlled. RoboClaw expects PWM pulses (50Hz) on S1 and S2 to drive the motors when the mode is set to both RC modes. The center points are calibrated at start up. A pulse width of 1000us is the default for full reverse and 2000us is the default for full forward.

Connect the I/O pins S1 and S2 to the IOIO pins used as digital PWM outputs (e.g. 3, 4, see documentation IOIO OTG), using 22AWG wires. The pins closest to the board edge on the motor

controller are the I/Os, center pin is the +5V and the inside pins are ground.

3. Controlling the servos

The servos are also controlled by PWM signals (50Hz). Connect the yellow/white wire to the IOIO pins 5 and 6 using 22AWG wires. Certain IOIO pins (e.g. 5 and 6) can be used as digital PWM outputs (see documentation IOIO OTG). Usually, a pulse width of 1000us turns the servo completely to the left, 1500us centers the servo, and 2000ms turns the servo completely to the right.

4. Finding distances from sonars

There are different ways to read data from the sonars (see Maxbotix online tutorials and documentation). The interface output formats included are pulse width output, analog voltage output, and RS232 serial output. The simplest way is to read an analog voltage from the *AN* pin of the sonars. To do so, connect the *AN* pin of the sonars to the IOIO pins used as analog inputs (e.g. 42, 43, 44, 45).

In order to find the range in inches, you will need to convert the voltage the following way:

First, calculate the scaling factor:

Vi = Vcc / 512

With Vi: Volts per inch (Scaling), Vcc: Supplied Voltage

Here, Vcc is 3.3V so:
Vi = 3.3V / 512 = 0.0064453125V per inch

Once you know the voltage scaling it is easy to properly calculate the range. The range formula is:

Ri = Vm / Vi

With Ri: Range in inches, Vm: Measured Voltage from the *AN* pin, Vi: Volts per Inch (Scaling)

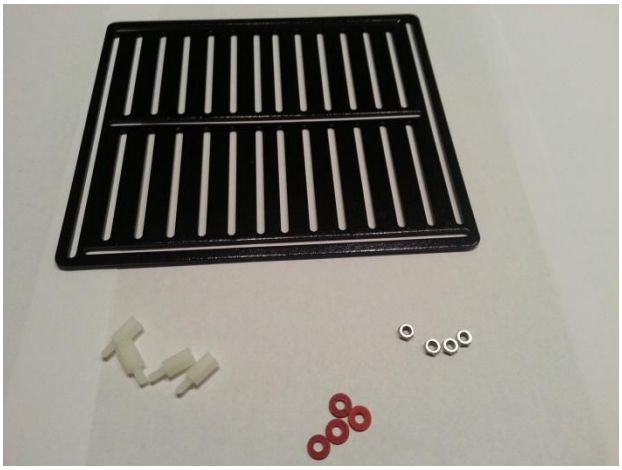
So we have:
Ri = Vm / 0.0064453125V

To get more accurate measurement, you might want to use the PW output of the sonars (sends PWM signal). You can connect the PW pin of a sonar to a digital pulse input on the IOIO (see documentation).

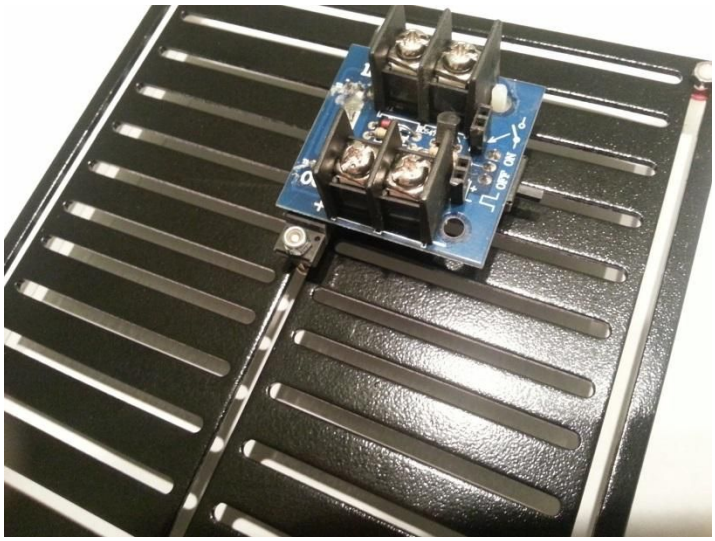
VI. TESTING COMPONENTS

A. Hardware

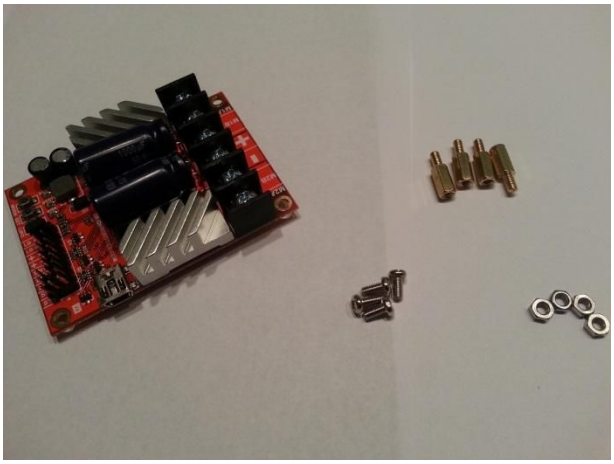
1. Screw standoffs to lower part of prototyping plate



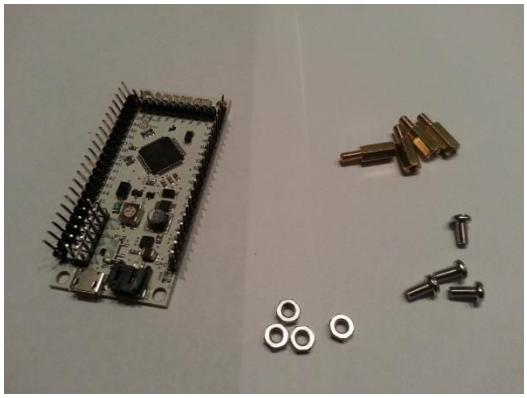
2. mount the high power switch on the plate

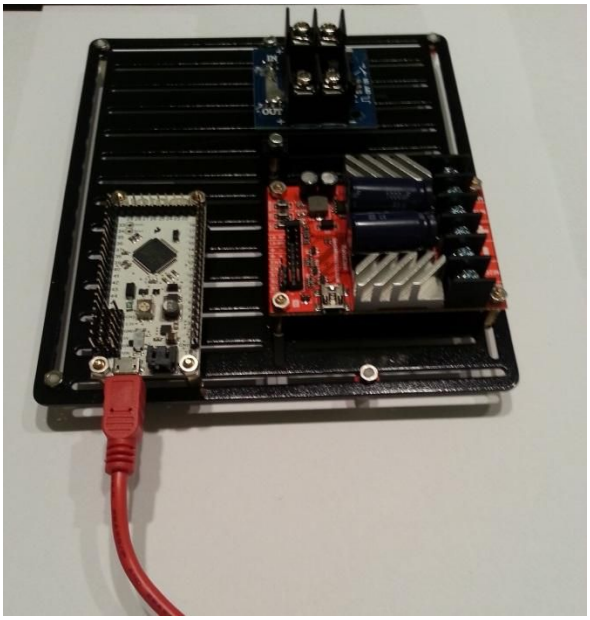


3. mount the motor controller on the plate

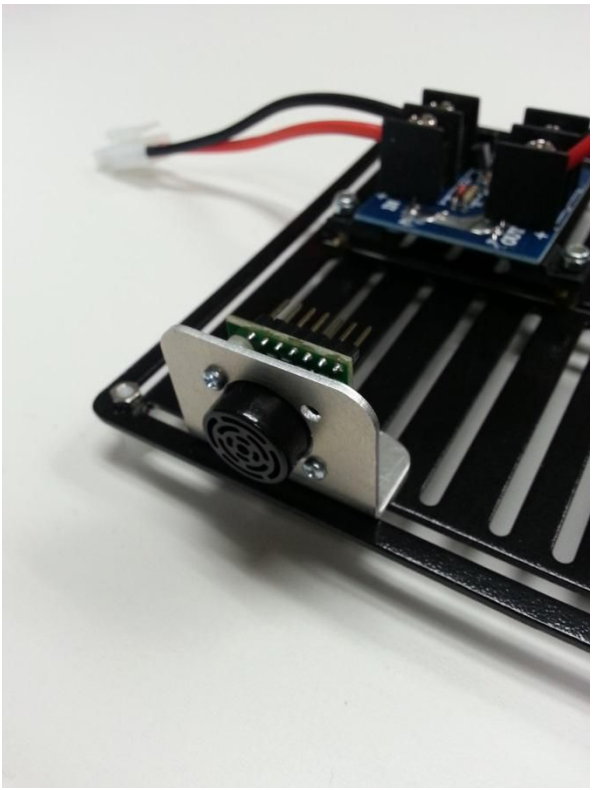


4. mount the IOIO on the plate

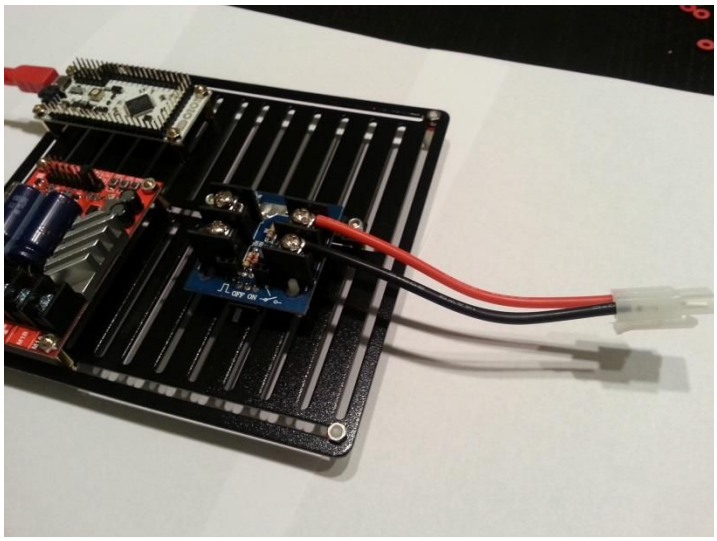




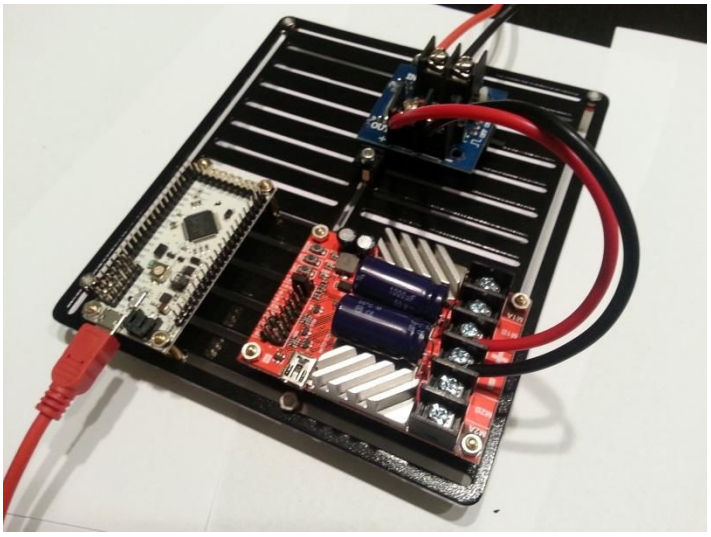
5. mount a sonar on the plate (assemble it first)



6. screw the Tamiya connector/wire to the power switch: IN + (red) and – (black)

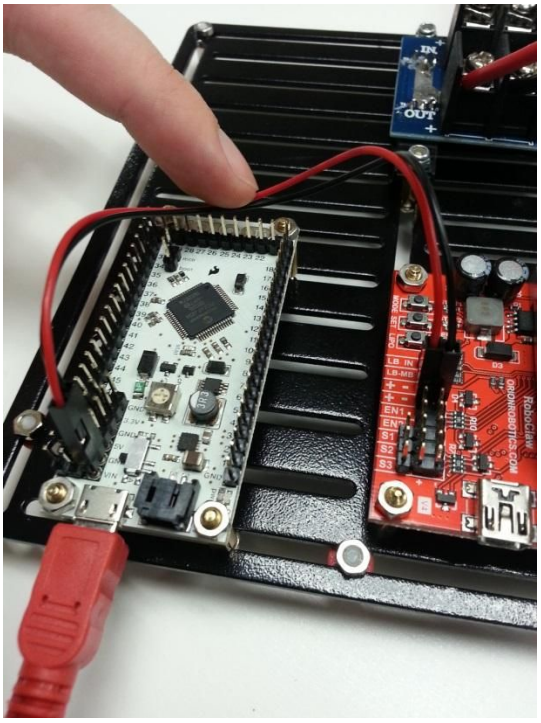


7. Use 14 AWG wires to connect the switch to the motor controller: OUT (+ -) to controller (+ -)

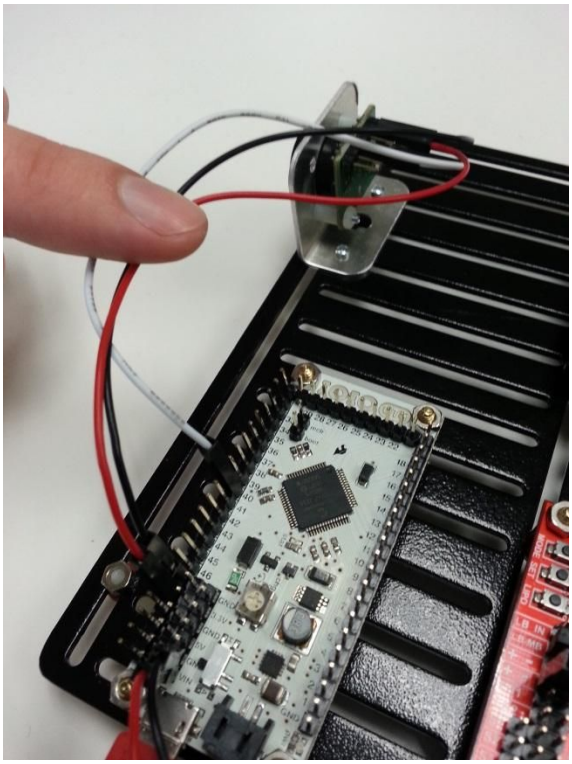


8. Use 22AWG wires with pre-crimped terminals to connect:

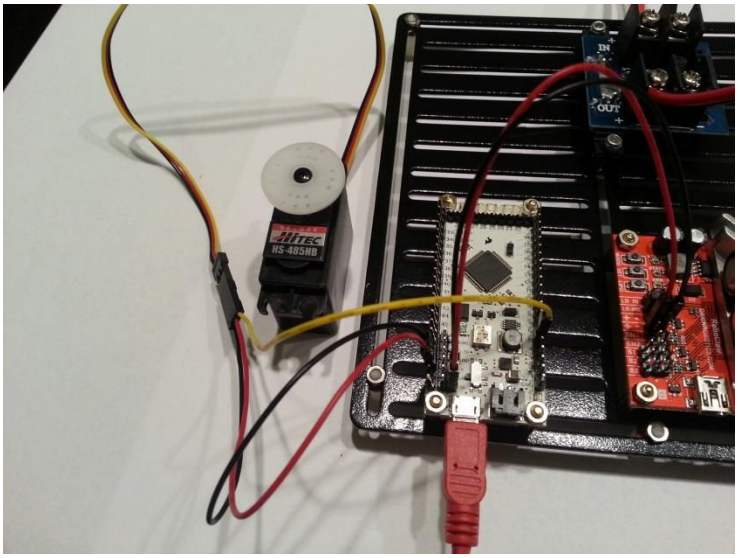
    - The motor controller (encoder power + -) to the IOIO (Vin, GND) using female-female wires



    - A sonar to IOIO (3.3V, GND, analog pin 40), using female-female wires



- A HS-485HB servo to the IOIO (5V, GND, PWM pin 5), using male-female wires

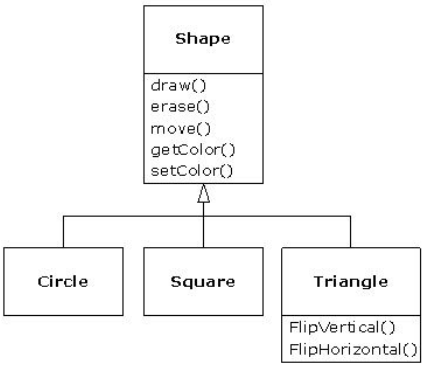


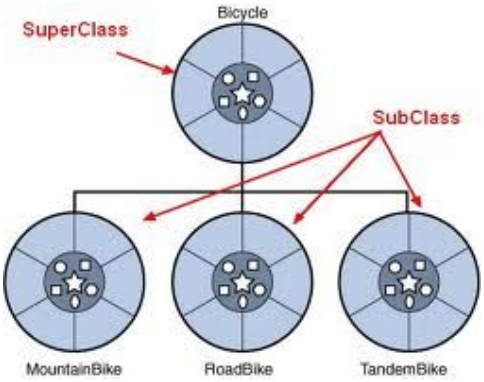
9. Plug battery to Tamiya connector (switch)

10. Turn switch on: check if the LEDs of the motor controller and the IOIO are lit.

B. Software

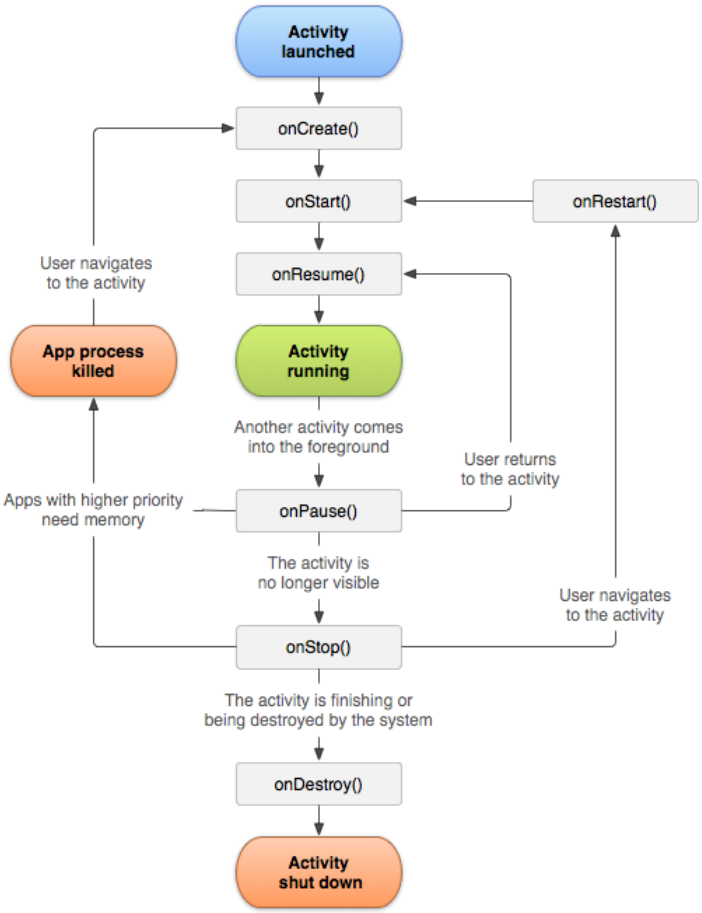
1. Quick introduction to object oriented programming (if necessary)
   Inheritance:





Inherit class: ***extends***
Inherit interface: ***implements***
Override function: ***@Override***

2. Introduction to Android activity



3. Open Android Studio
    - Choose workspace location (e.g. where you copied the IOIO libraries)

4. Import IOIO libraries and projects

5. Open IOIOSimpleApp project
    - Description of the different Android project files
    - Description of the IOIOSimpleApp activity and IOIO library (PWM output, analog input)

6. Modify the IOIOSimpleApp activity to read an analog value from the sonar and control the servo connected to the IOIO. Display the actual range in inches detected by the sonar.

7. If there is time:
    - explain different modes of motor controller (see RoboClaw documentation)
    - Choose RC mode
    - Mount plate on robot
    - Connect the motors to the controller using 14AWG wires
    - Modify the app the control the motors using the slider/seekbar

For more examples, go to:

- https://github.com/UCI-ABR
- Search for IOIO tutorials / examples online

VII. DOCUMENTATION

Android based robotics

- http://www.socsci.uci.edu/~jkrichma/ABR/
- https://groups.google.com/forum/?hl=en#!forum/android-based-robotics
- https://github.com/UCI-ABR

Android

- http://developer.android.com/about/index.html
- http://developer.android.com/sdk/index.html
- Tons of free tutorials and online courses (Coursera…)

IOIO OTG

- https://github.com/ytai/ioio/wiki
- https://groups.google.com/forum/#!forum/ioio-users
- https://www.sparkfun.com/tutorials/280
- https://github.com/ytai/ioio/wiki/Supported-Devices
- Also, take a look at: IOIOScript , Protocoder, B4A (Basic for Android) for programming

Arduino MEGA ADK R3

- http://developer.android.com/tools/adk/index.html

Sonars LV MaxSonar EZ0:

- http://www.maxbotix.com/documents/MB1000_Datasheet.pdf
- http://www.maxbotix.com/tutorials.htm

Robot chassis (Wild Thumper 6WD):

- https://www.dropbox.com/s/k37afb8v6qr3ly5/4WD%206WD%20short%20manual.pdf?dl=0

High power switch

- http://www.jameco.com/Jameco/Products/ProdDS/2150521.pdf
- http://letsmakerobots.com/content/high-power-switch

Motor controller (RoboClaw 2x30A):

- http://downloads.orionrobotics.com/downloads/datasheets/roboclaw_user_manual.pdf
- https://www.pololu.com/product/3286

Computer vision libraries for Android

- http://opencv.org/platforms/android.html
- https://developer.qualcomm.com/mobile-development/add-advanced-features/computer-vision-fastcv

ROS Android

- http://wiki.ros.org/android

VIII. PARTS LIST

Parts / Items	Unit price	Quantity	Total Price	Vendor link
Dagu Wild Thumper 6WD 75:1	250	1	250	http://www.pololu.com/product/1563
RoboClaw 2x30A Motor Controller	124	1	124	https://www.pololu.com/product/3286
Tamiya Plug with 10cm Leads, Female 14AWG	1.49	2	2.98	http://www.pololu.com/product/2172
Wires with Pre-crimped Terminals 50-Piece Rainbow Assortment F-F 6"	9.95	1	9.95	http://www.pololu.com/product/1800
Wires with Pre-crimped Terminals 50-Piece Rainbow Assortment M-F 6"	9.95	1	9.95	http://www.pololu.com/product/1801
Stranded Wire: White, 22 AWG, 50 Feet	5	1	5	http://www.pololu.com/product/2649
Stranded Wire: black 22 AWG, 50 Feet	5	1	5	http://www.pololu.com/product/2640
Stranded Wire: red 22 AWG, 50 Feet	5	1	5	http://www.pololu.com/product/2642
0.1" (2.54 mm) Breakaway Male Header: 1x40-Pin, Straight	1	2	2	http://www.pololu.com/product/965
0.1" (2.54mm) Crimp Connector Housing: 1x1-Pin 25-Pack	0.6	4	2.4	http://www.pololu.com/product/1900
Female Crimp Pins for 0.1" Housings 100-Pack	6	1	6	http://www.pololu.com/product/1930
JR Connector Pack (3 connectors), Male	3	4	12	http://www.pololu.com/product/1925
JR Connector Pack (3 connectors), Female	2	4	8	http://www.pololu.com/product/1924
Twisted Servo Extension Cable 12" Female - Female	2.75	2	5.5	http://www.pololu.com/product/2166
Twisted Servo Extension Cable 12" Male - Female	2.75	7	19.25	http://www.pololu.com/product/2169
Arduino MEGA ADK R3 for Android	48.05	1	48.05	http://www.amazon.com/Arduino-MEGA-ADK-R3-Android/dp/B007BT37BC
bluetooth dongle	11	1	11	http://www.amazon.com/Satechi-Bluetooth-Adapter-Windows-compatible/dp/B008BC1U4O/ref=sr_1_3?s=electronics&ie=UTF8&qid=1414969497&sr=1-3&keywords=bluetooth+dongle
RetiCAM® Smartphone Tripod Mount	25	1	25	http://www.amazon.com/RetiCAM%C2%AE-Smartphone-Tripod-Mount-Universal/dp/B00FS5L9D4/
DuraTrax NiMH Onyx 7.2V 5000mAh	35	2	70	http://www.amazon.com/Duratrax-NiMH-5000mAh-Stick-Standard/dp/B004AF88K0/ref=sr_1_cc_1?s=aps&ie=UTF8&qid=1414970891&sr=1-1-catcorr&keywords=DuraTrax+NiMH+Onyx+7.2V+5000mAh
Duratrax Onyx 200 AC/DC Sport Peak Charger NiMH bat.	45	1	45	http://www.amazon.com/Duratrax-Onyx-Sport-Peak-Charger/dp/B001BCF4YS/ref=sr_1_1?s=toys-and-games&ie=UTF8&qid=1414971105&sr=1-1&keywords=DuraTrax+Onyx+200
red wire 14AWG	6.49	1	6.49	http://www.amazon.com/Grand-General-55241-14-Gauge-Primary/dp/B00INVEUP4/ref=pd_bxgy_auto_text_y
black wire 14AWG	6.49	1	6.49	http://www.amazon.com/Grand-General-55240-14-Gauge-Primary/dp/B00INVEUNQ/ref=pd_bxgy_auto_text_y
Prototyping Plate	12	1	12	http://www.robotshop.com/en/dfrobot-prototyping-plate.html
servo Hitec HS-485HB	17	2	34	http://www.robotshop.com/en/hitec-hs-485hb-servo-motor.html
SPT200 Direct Drive Pan & Tilt System	46	1	46	http://www.robotshop.com/en/servocity-spt200-pan-tilt.html
SPT200 base mount with spacers/standoffs	12	1	12	http://www.robotshop.com/en/direct-drive-pan-base-mount-spt200-or-ddp125.html
power switch	2.95	1	2.95	http://www.robotshop.com/en/illuminated-toggle-switch-red.html
maxbotix sonar (LV MaxSonar EZ0)	30	4	120	http://www.superdroidrobots.com/shop/item.aspx/lv-maxsonar-ez0-ultrasonic-range-finder/830/
sonars mount	6	4	24	http://www.superdroidrobots.com/shop/item.aspx/single-maxbotix-sonar-servo-arm-bracket/1644/
IOIO OTG	40	1	40	https://www.sparkfun.com/products/13613

High Power Switch	18.51	1	18.51	https://robosavvy.com/store/dagu-wild-thumper-high-power-switch.html