Building the Builder Robot

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The **Builder Robot** is a complete mobile robotics platform and includes an arm with a gripper and an active vision system. This report describes the steps to put together the robot from 3D printed files. Instructions are also included on how to assemble the electronic systems of the robot. The intention is that it should be possible to build the robot by following the steps in the report.

The main parts of the builder robot are the sensory systems, locomotor systems, arm with gripper and the on-board computer running the Ikaros system (Balkenius, et al. 2010).

Sensory Systems Each camera is mounted on a servo that allows it to move up or down. The robot can also measure the voltage and the current it uses. This can be used to estimate the power used by the robot at any time. In addition, all servos provides information about their current position, their temperature and other data.

Locomotion System The locomotion system uses a holonomic drive system with four Mecanum wheels mounted on servos. This allows the robot to move in any direction on the ground.

Arm and Gripper The arm has five degrees of freedom and a gripper that allows it to pick up and manipulate objects. The arm and gripper is controlled using seven servos. Each servo system provides feedback about the current position of each joint.

On Board Computers The Builder Robot has a Mac Mini on board that is modified to run off battery. There is an Arduino Mega that is used to control the LED strip around the body of the robot.

Ikaros Control System The Ikaros framework (www.ikaros-project.org) provides the robot with features such as real-time sensory processing and motor control, threading, web based monitor interface, and a selection of over 200 modules for various processing and control functions (Balkenius, et al. 2010). The internal state of the robot (sensor values, navigation, etc.) can be monitored remotely from a web browser over WiFi.

Building the robot involves main steps:

A.   Download the STL-files for the robots from Thingiverse:

    http://www.thingiverse.com/birgerjohansson/collections/builder-robot

B.   Print all the parts with support. We used a Makerbot Replicator 2 with default settings for PLA for the robot shown in the figures below, except for parts N that were printed in NinjaFlex on a Replicator Dual.

C.   Remove the support material.

D.   Follow the instructions below on assembly

E.   Install the Ikaros system on the Mac Mini as described here: http://www.ikaros-project.org/installing/osx/

The following pages shows the different parts and the steps needed to build the robot

The different 3D-printed parts. A-L
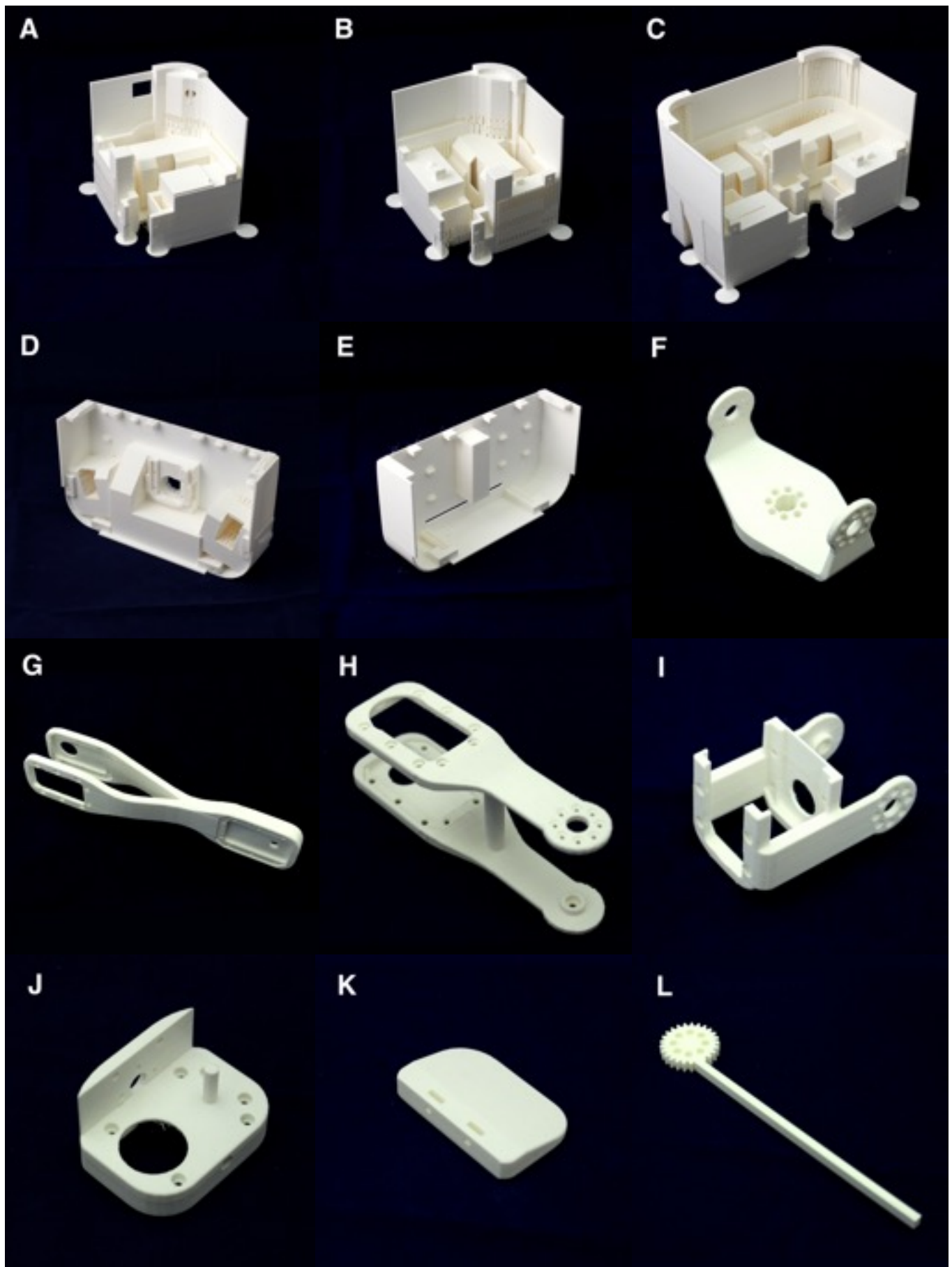
Parts M-Q
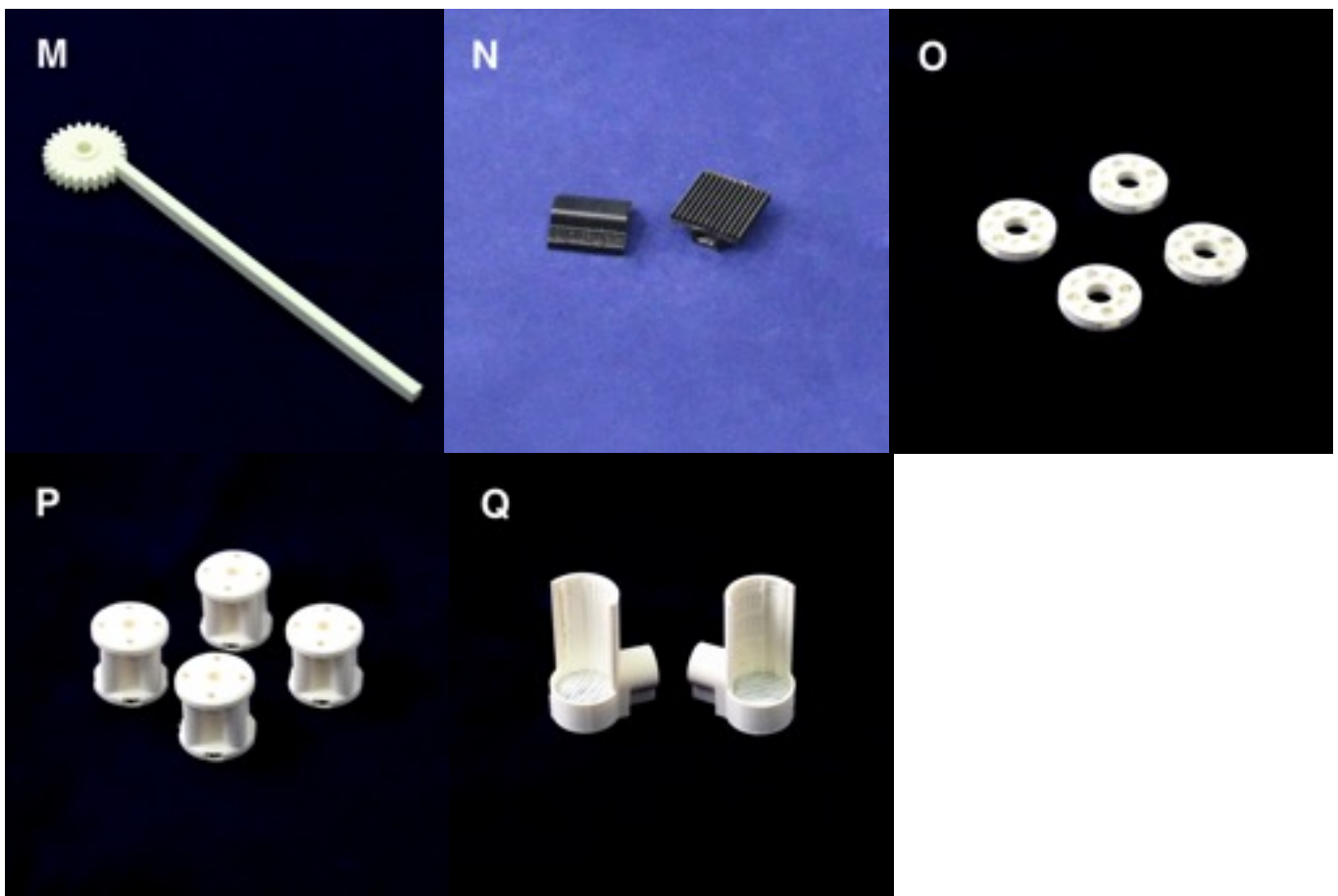
Thirteen of the 24 parts (A-L)
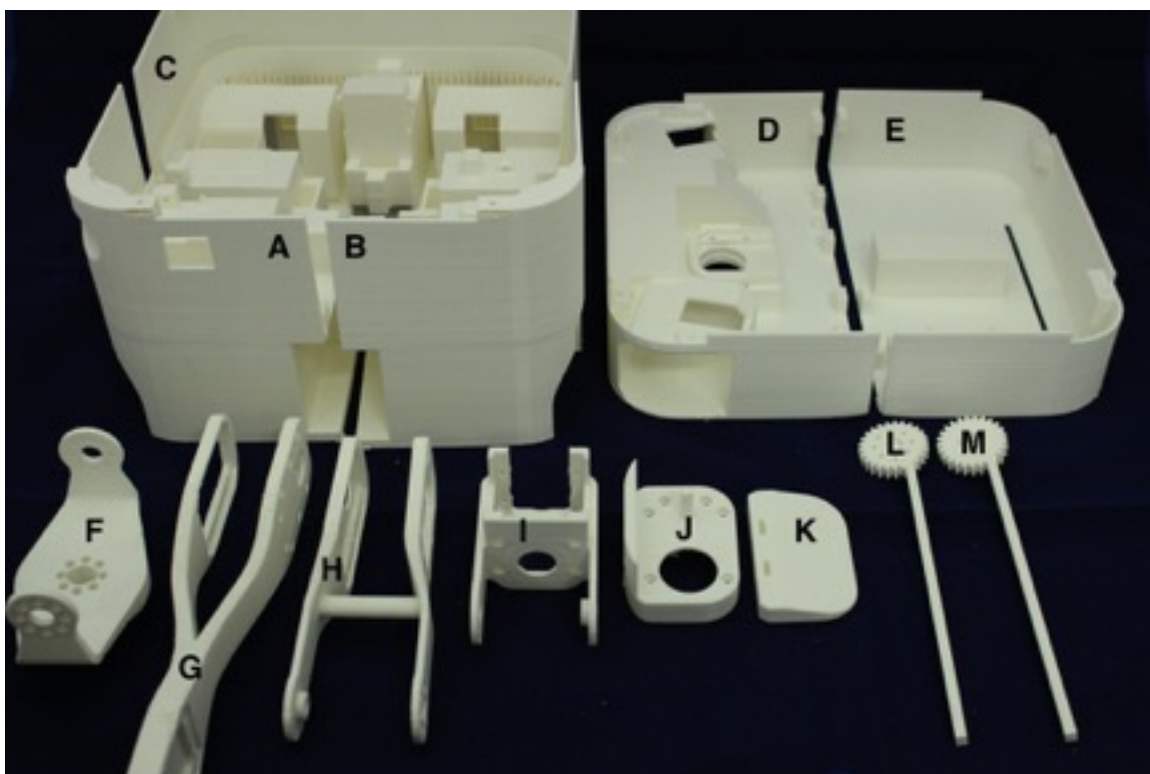
Step 1
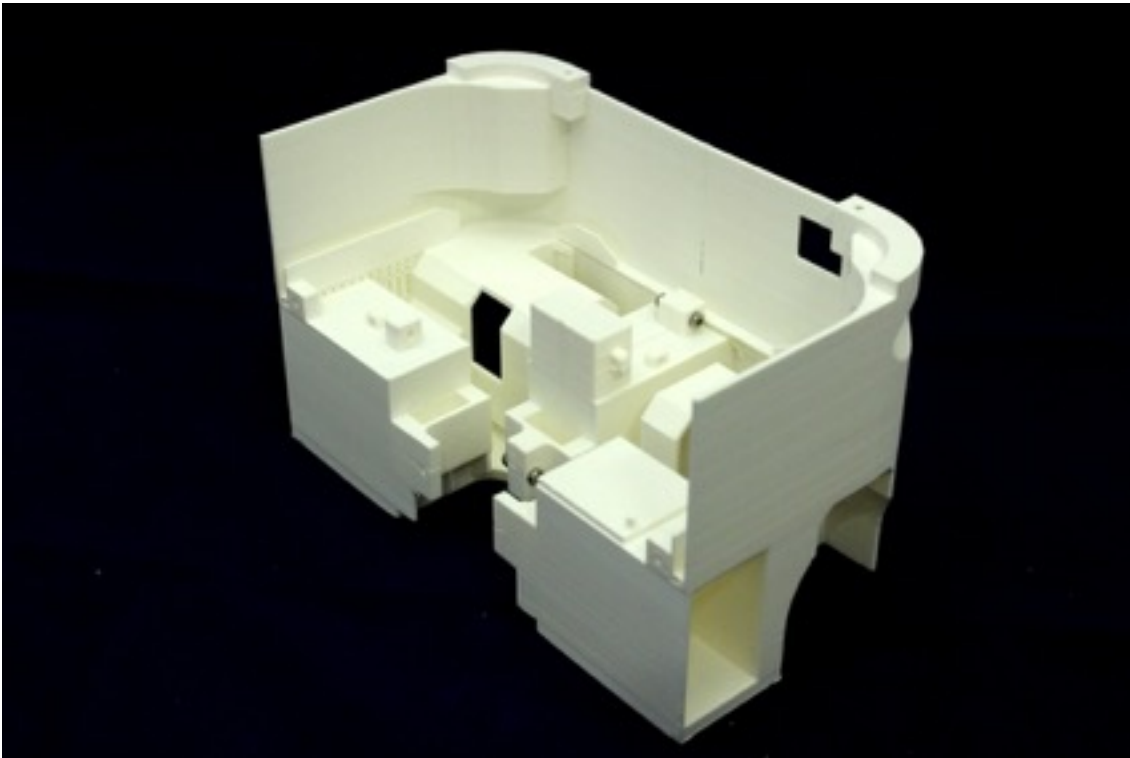
Put the lower back pieces (A and B) of the robot together.

Step 2
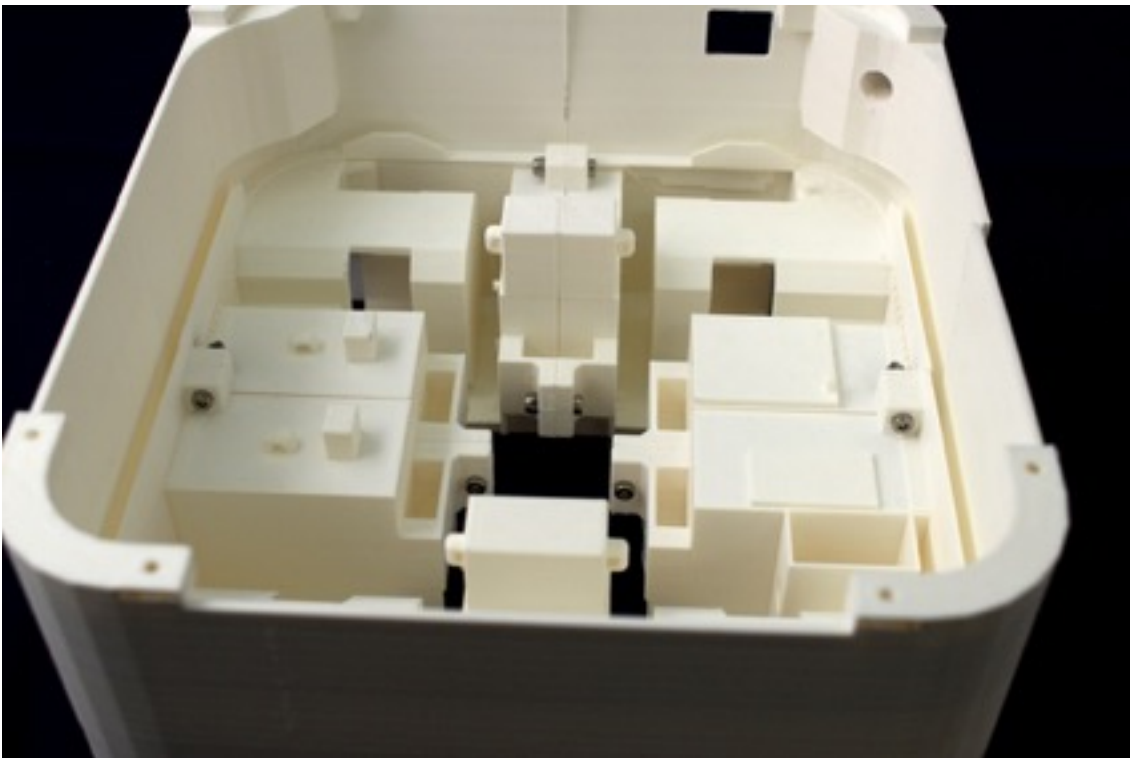
Add the lower front part (C) of the robot together with the assembled parts (A+B). Also put the top parts (D+E) of the robot together.

Step 3

Mount three servos on first link of the robot arm (G). Make sure that the servos goes all the way in and that no left over support is blocking them.

Step 4

Carefully mount a servo onto the second link of the robot arm (H) by gently bending it apart.

Step 5

Mount a servo onto the third link (I) of the robot arm.

Step 6

Mount a servo onto the fourth link (J) of the robot arm and put the third (I) and fourth part together (J).

Step 7

Add the two gripper pieces (L and M) onto the forth arm part (J). Make sure that the gripper parts are align with each other.

Step 8

Lock the gripper pieces (L and M) by putting the lock part (K) onto the fourth arm part (J).

Step 9
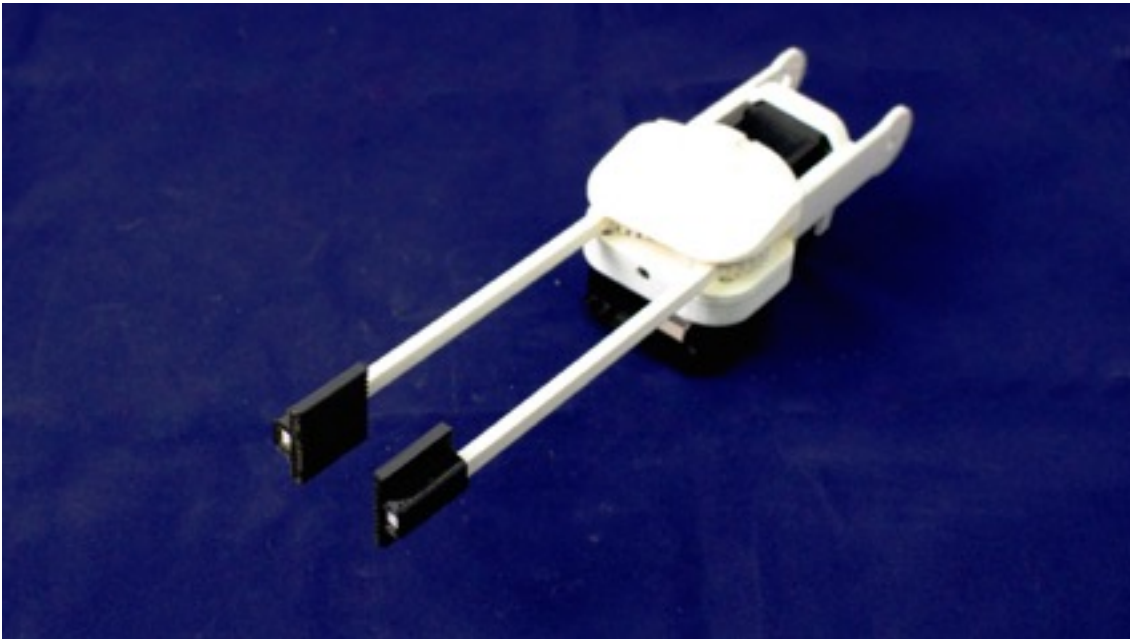
Add the rubber pads (N) to the grippers (L and M).

Step 10

Put together the forth (J) and the third (H) robot arm part.

Step 11
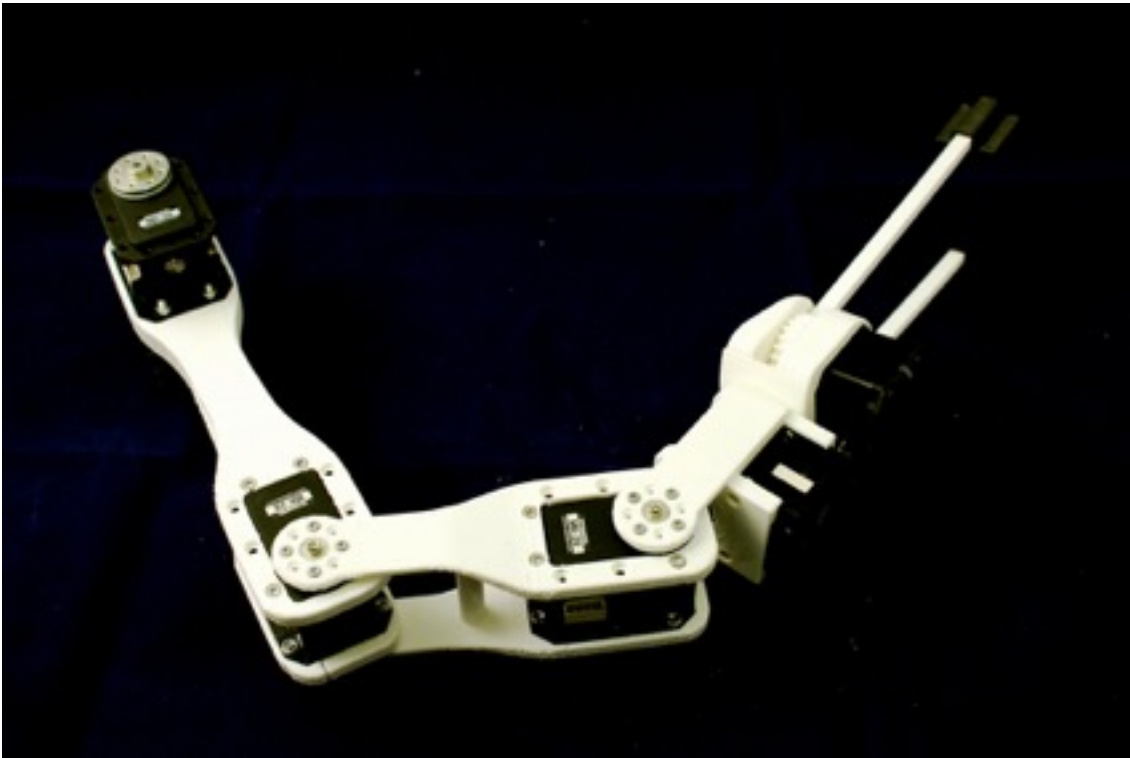
Put the first (H) and second (G) robot arm part together.

Step 12
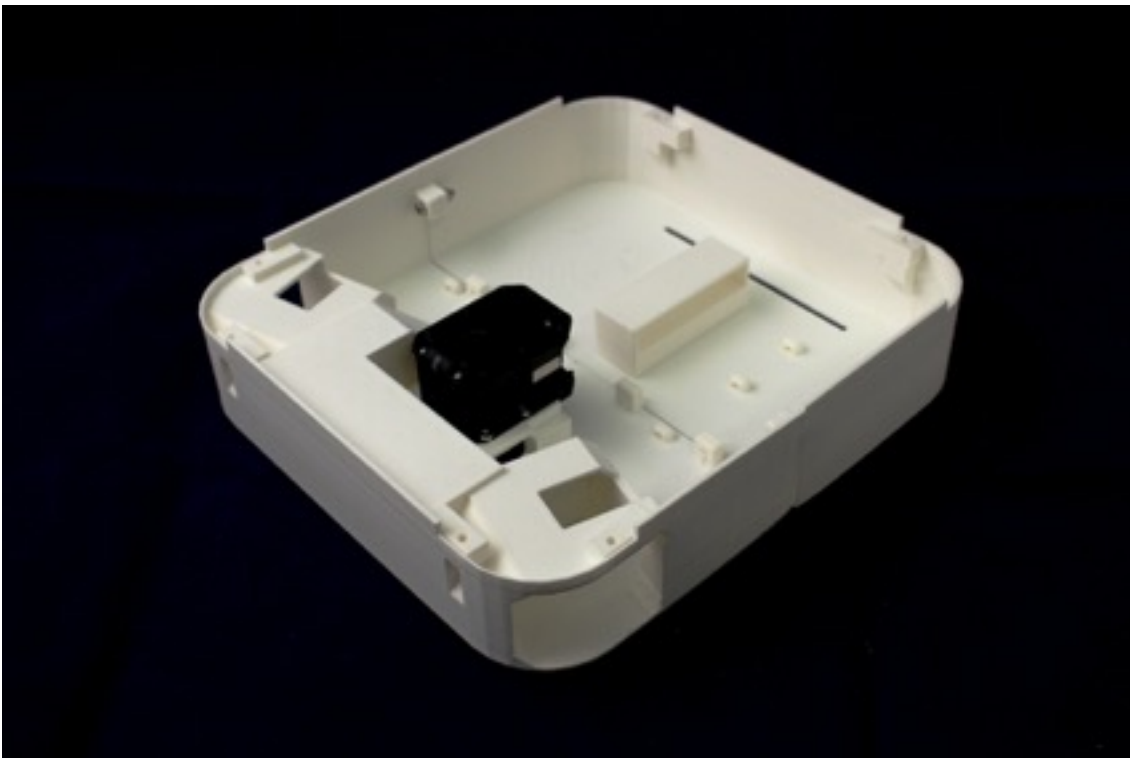
Mount a servo inside the top part of the robot (D).

Step 13

Turn the top part over and add the ball bearing.

Step 14

Mount the first part (F) of the robot arm to hold the ball bearing at place. Remember to include the arm servo cable though the first robot part (C+D).

Step 15

Put the arm (G-M) together with the top (F) of the robot.

Step 16

Add the wheel mounting part (O) onto four servos.

Step 17
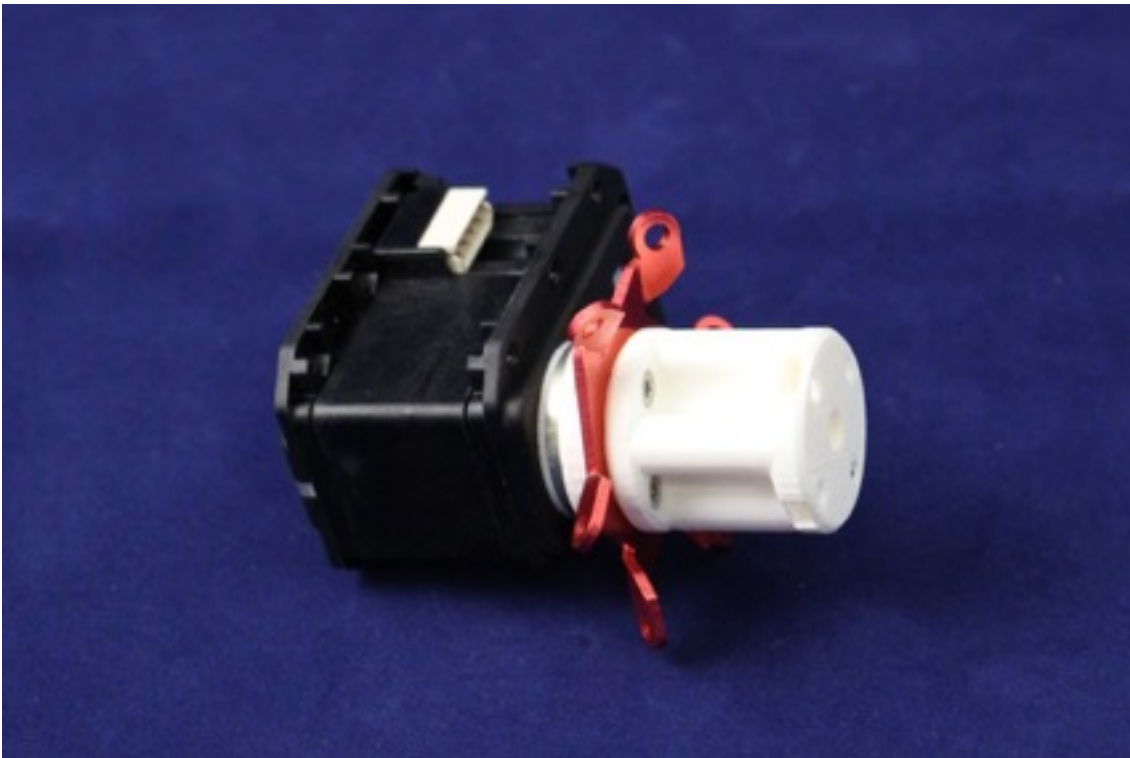
Add the inner part of the wheel and the distance part (P).

Step 18

Add the rest of the wheel parts and the outer wheel for each wheel.

Step 19
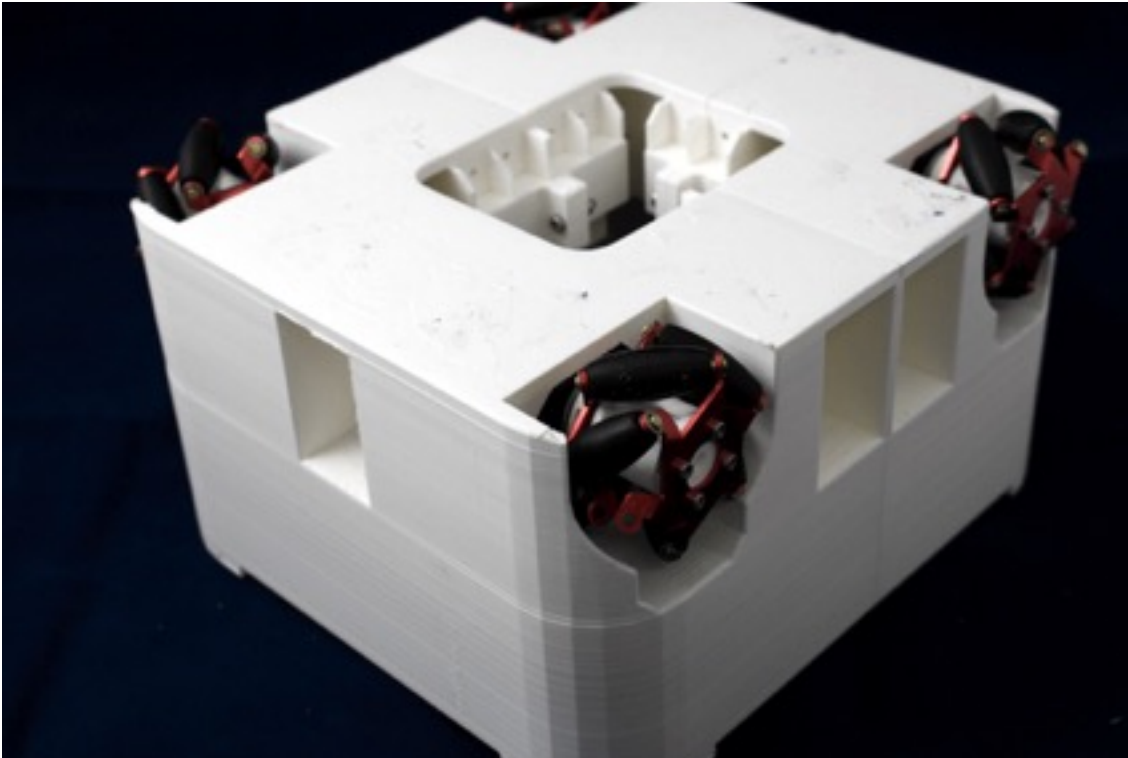
Push the wheel servos into the robot body. Make sure that there is no left over support and that the wheels have been assemble correctly.

Step 20

Push the cameras into camera holder parts (Q). The camera holder parts have a stop inside that will fixate the cameras orientation. Removing the camera can be tricky so make sure they are correctly inserted into the camera holder parts (Q).

Step 21
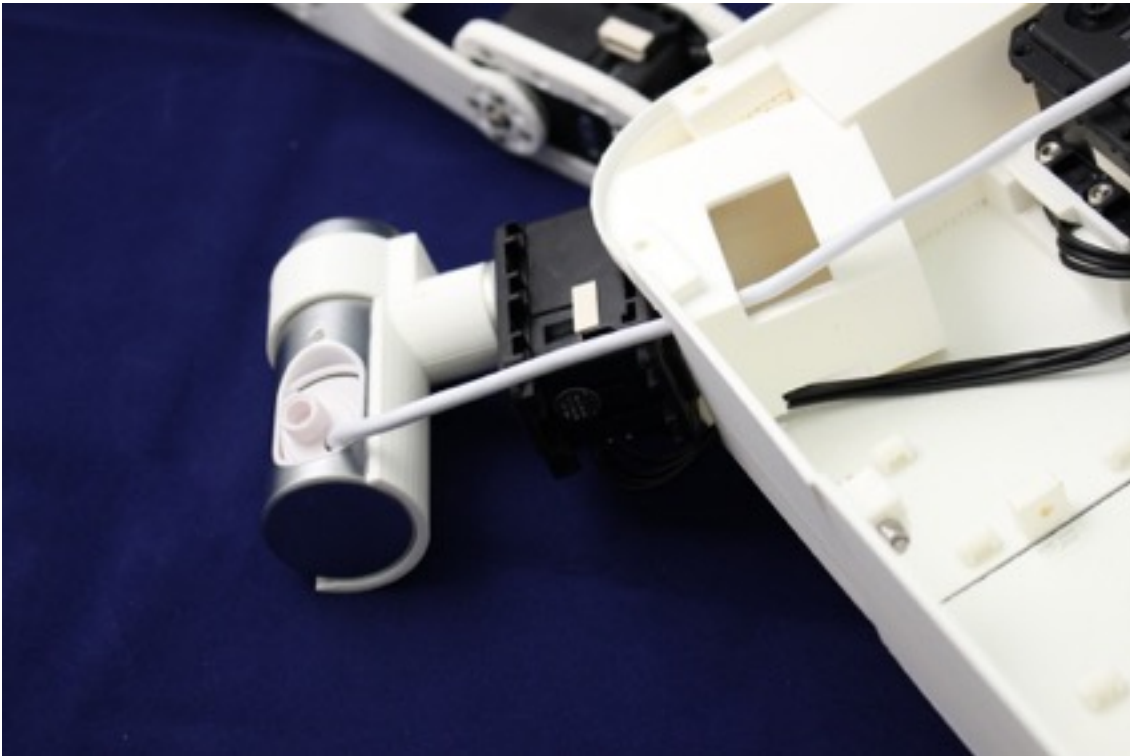
Put the servo wires and camera cable through the holes in the robot top and push the servo into the robot top.

Step 22

Set the ID of the servos.

Servo IDs

Wheels

Cameras

Arm
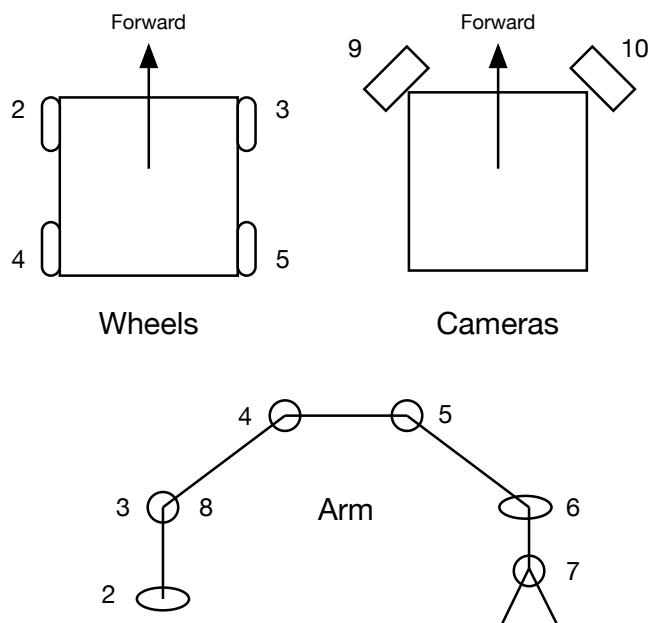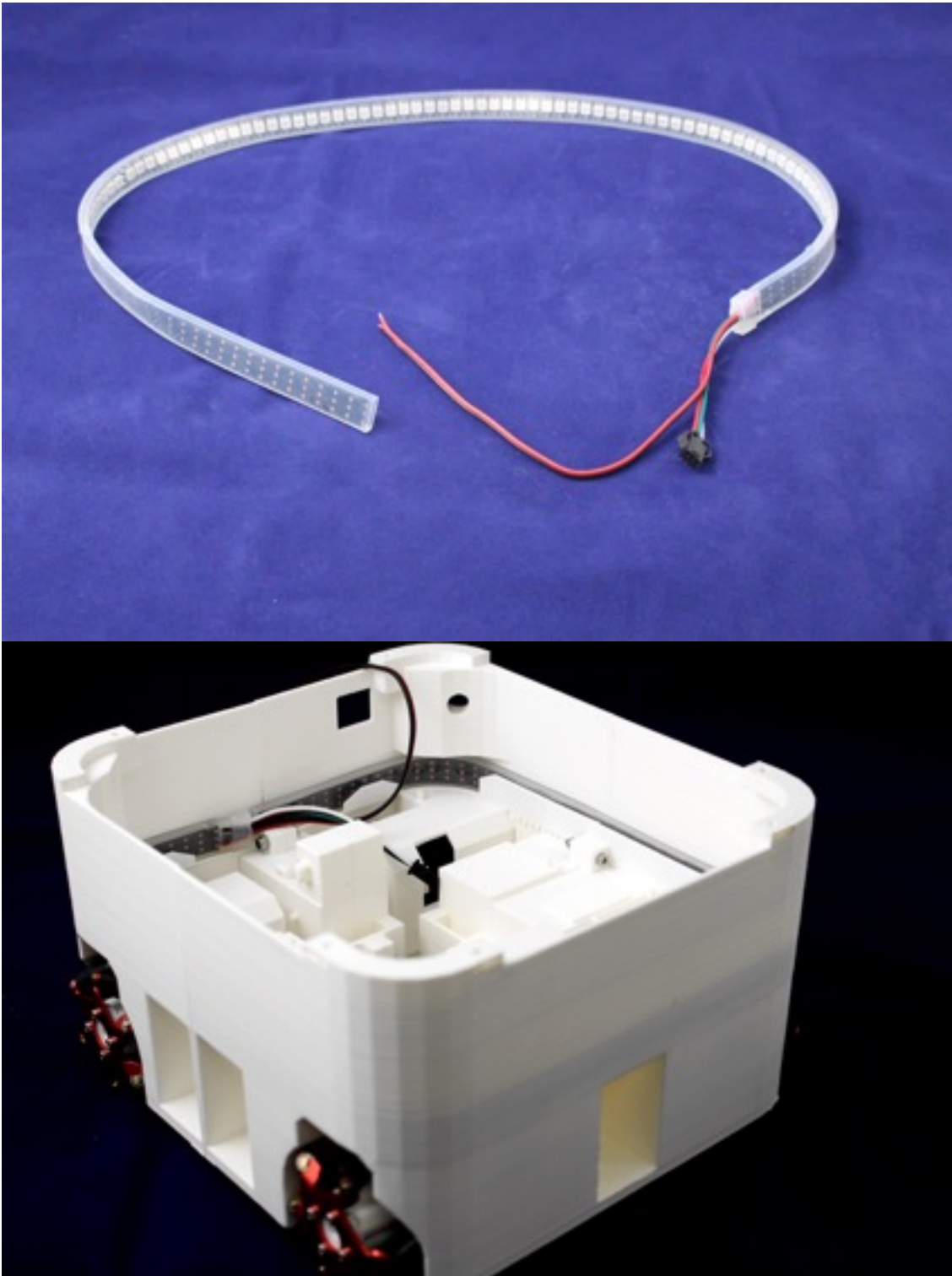
Step 23

Cut the LED strip at 74 cm and mount it inside the robot body as shown in the picture.

Step 24
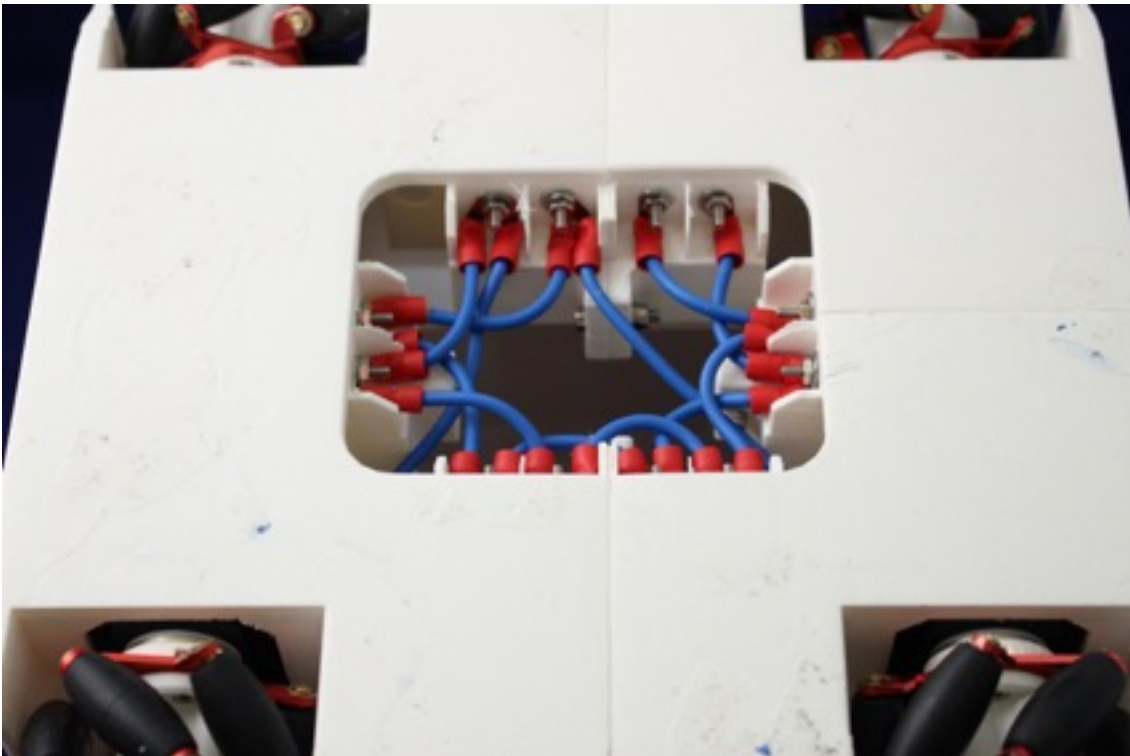
Turn the robot body upside down and mount the battery connectors and all the cables. All the batteries are connected in parallel.

Step 25
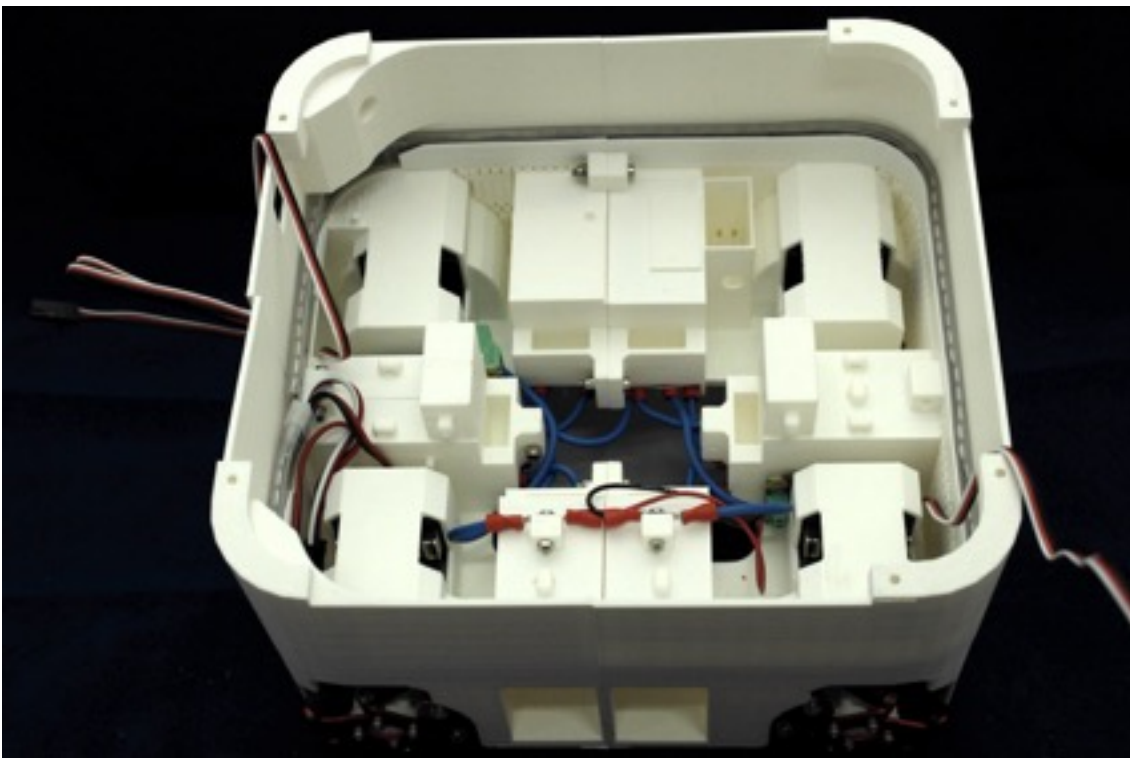
Add the current and voltage sensor to the power circuit.

Step 26
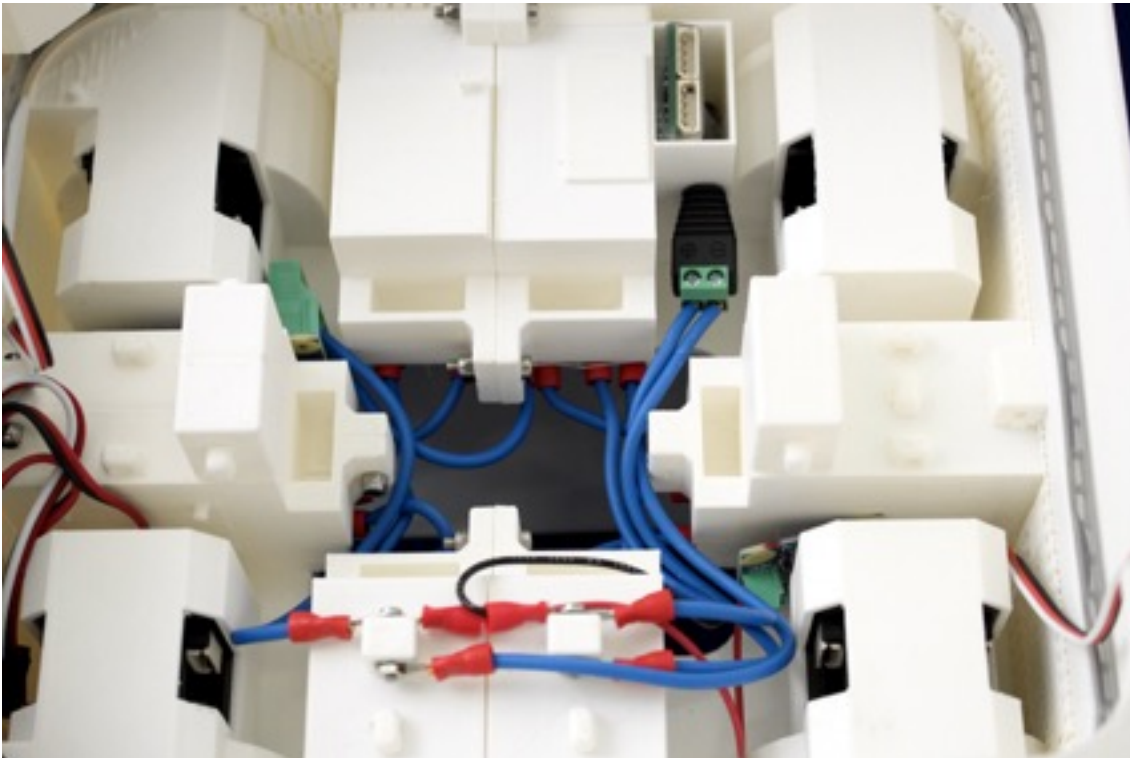
Connect the power circuit to the servo power supply.

Step 27
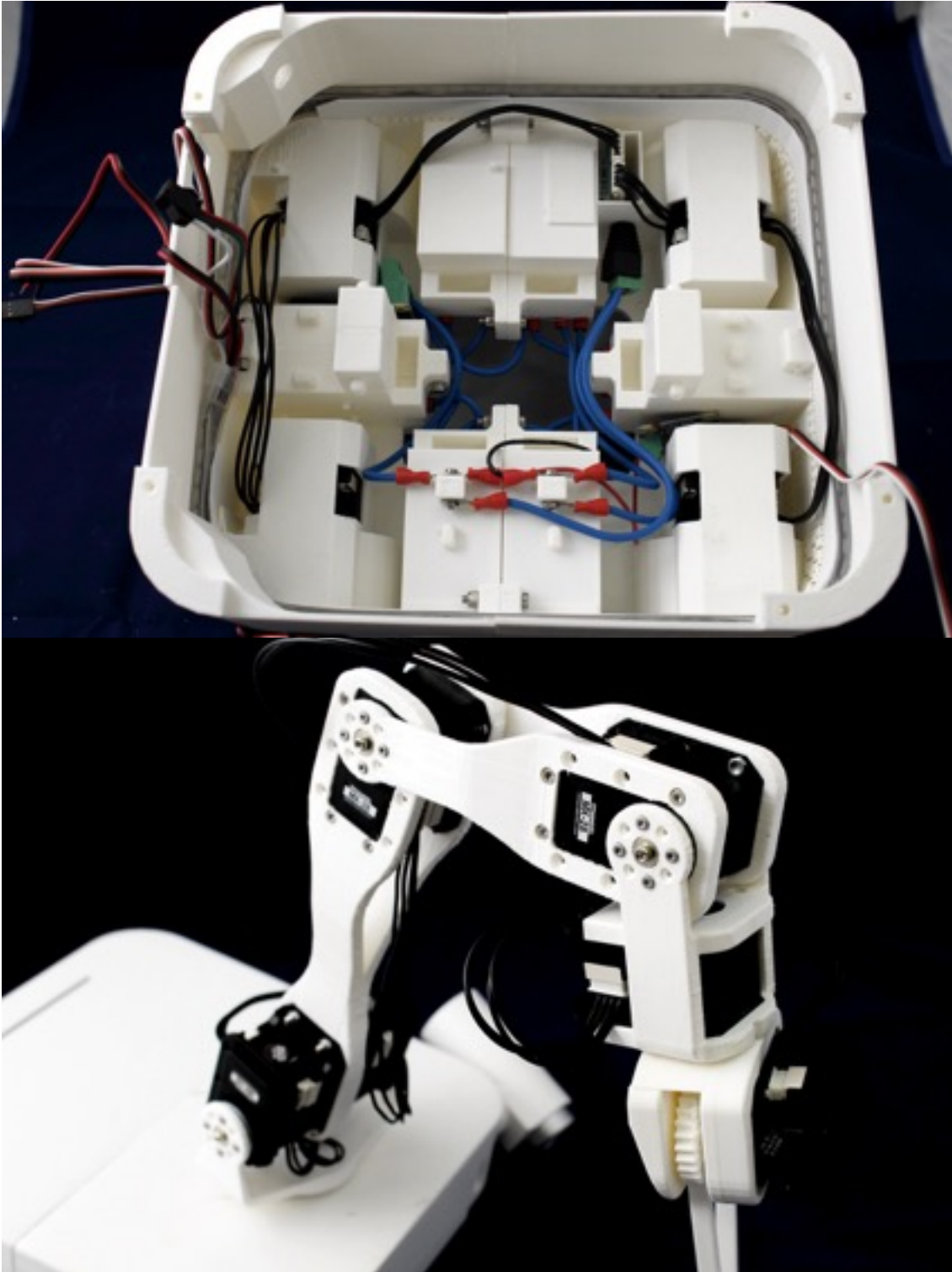
Connect the wheel servos and arm servos.

Step 28
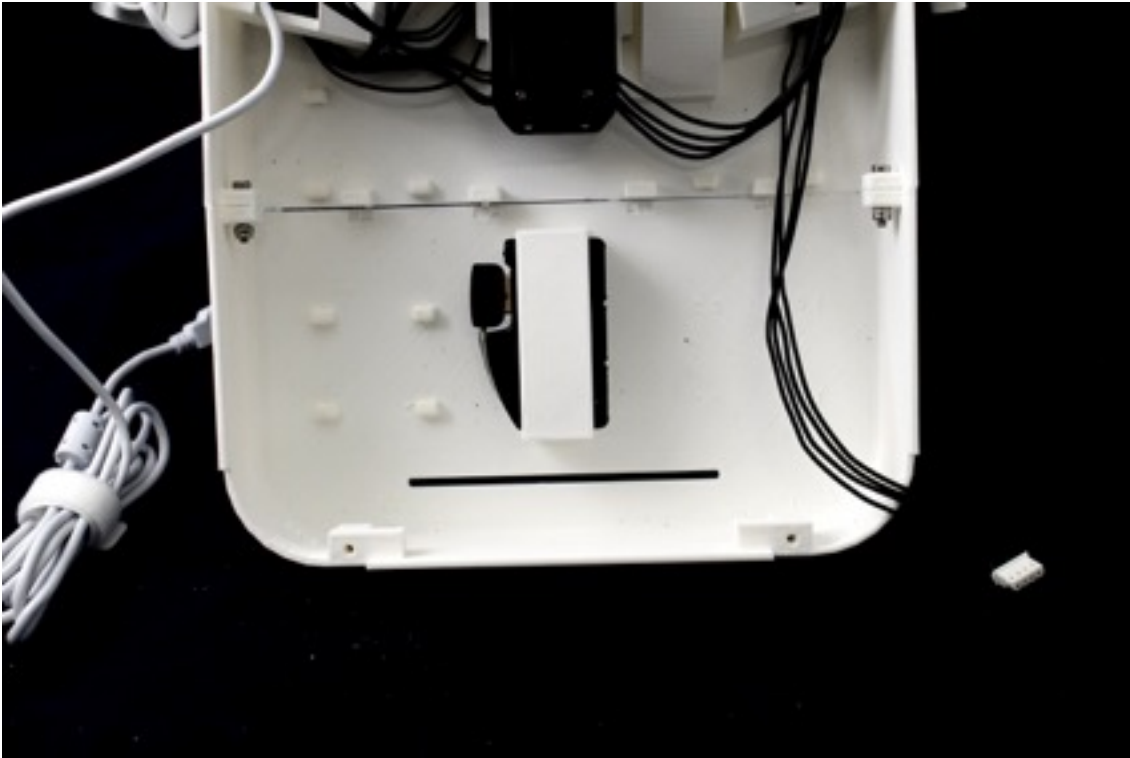
Mount the USB port inside the robot top part.

Step 29
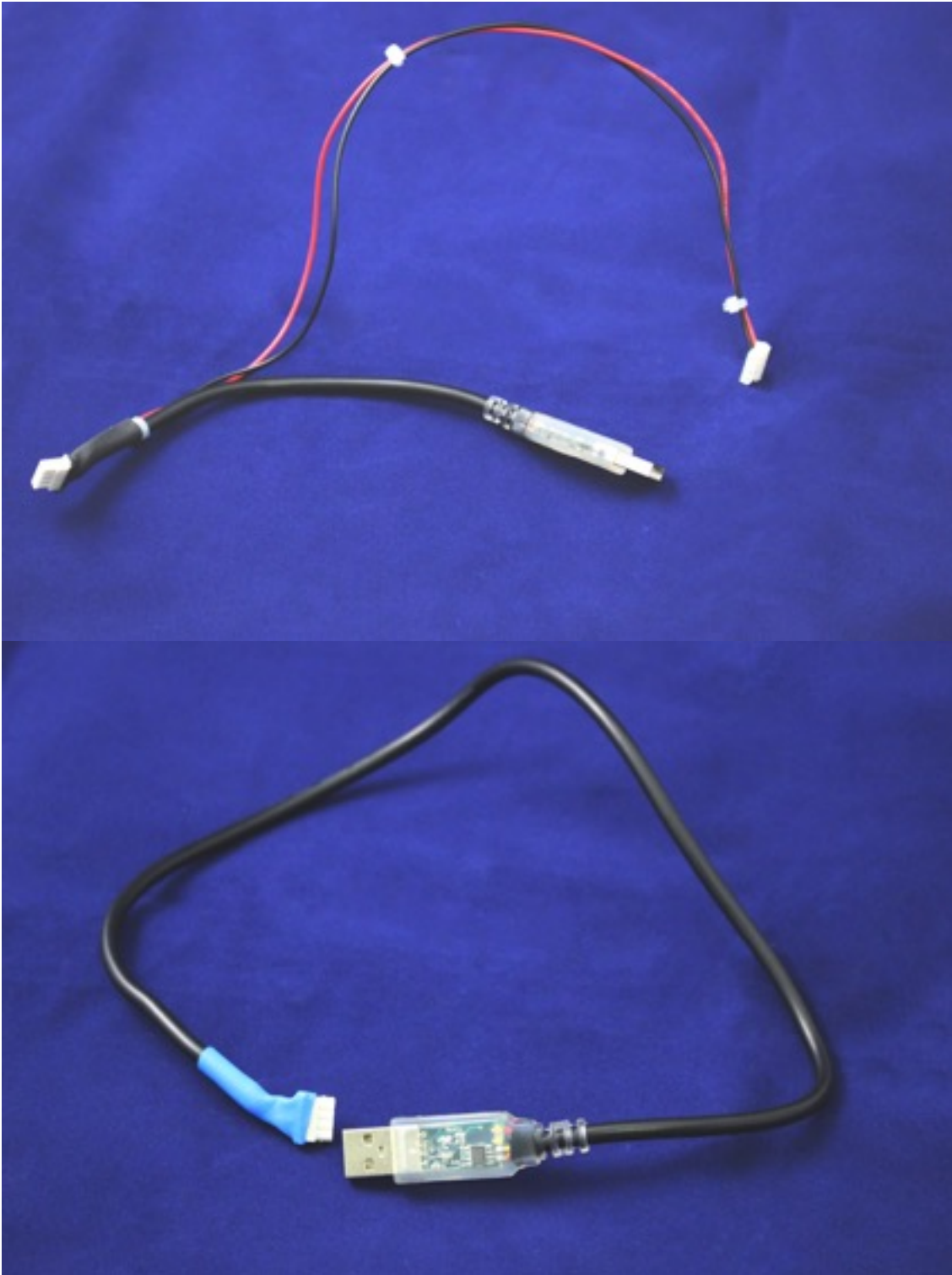
Make two USB to serial cables. All the servos are connected on the same power circuit but the serial data is split between the wheels and the reset of the servos.

Step 30
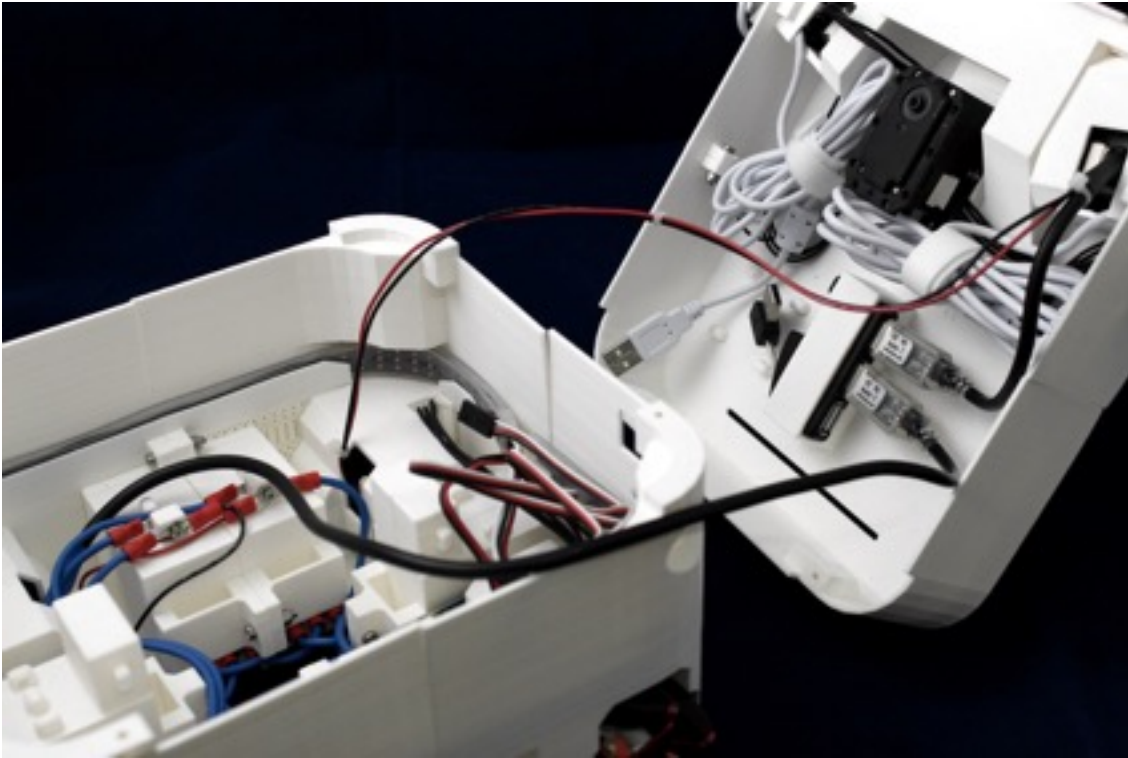
Install the cables from step 29.

Step 31

Modify the Mac Mini to operate on 12 volts by bypassing the power supply inside the mac mini.

Step 32
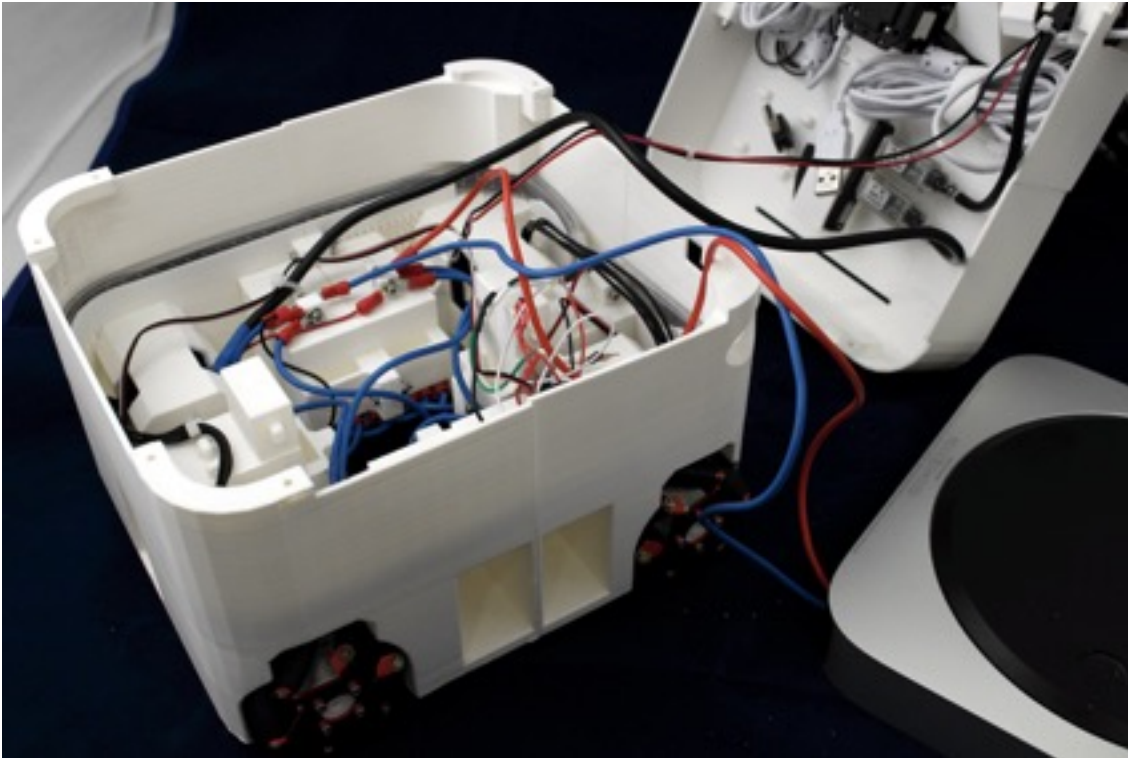
Connect the Mac Mini to the power circuit.

Step 33
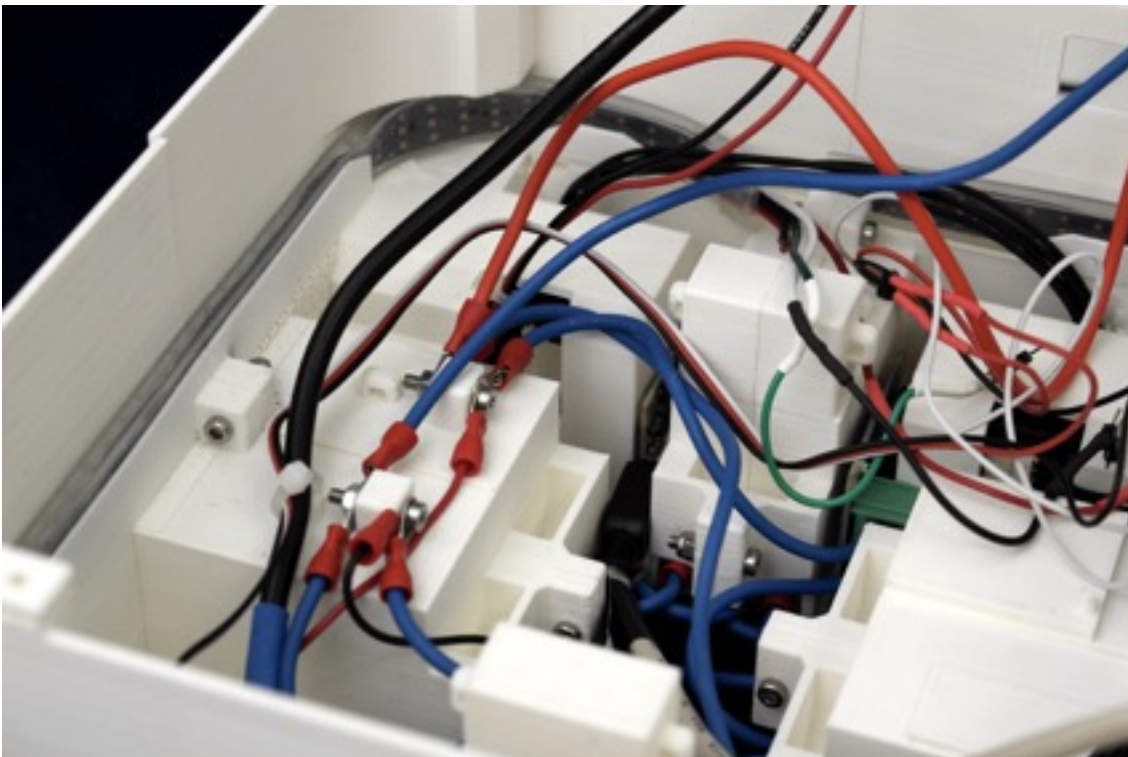
Mount the gyro inside the robot body as in the picture.

Step 34
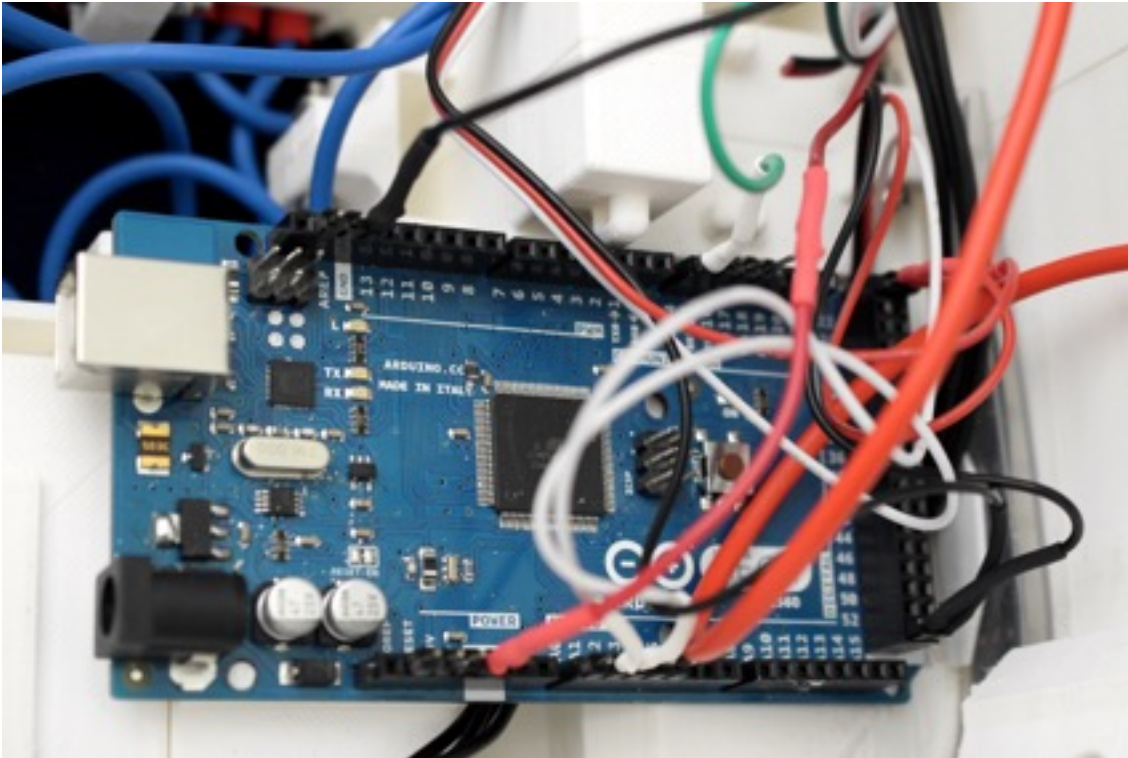
Mount the Arduino inside the robot body and connect the voltage, current and NeoPixel strip.

Step 35
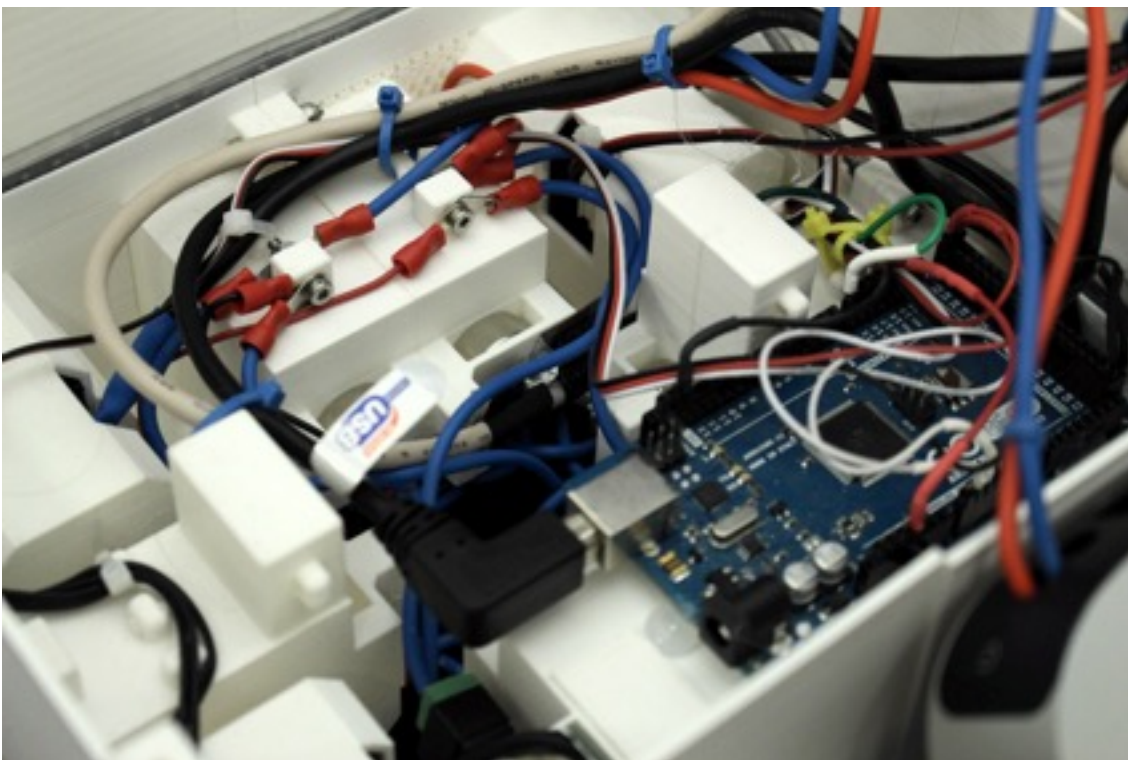
Hot glue any lose parts inside the robot.
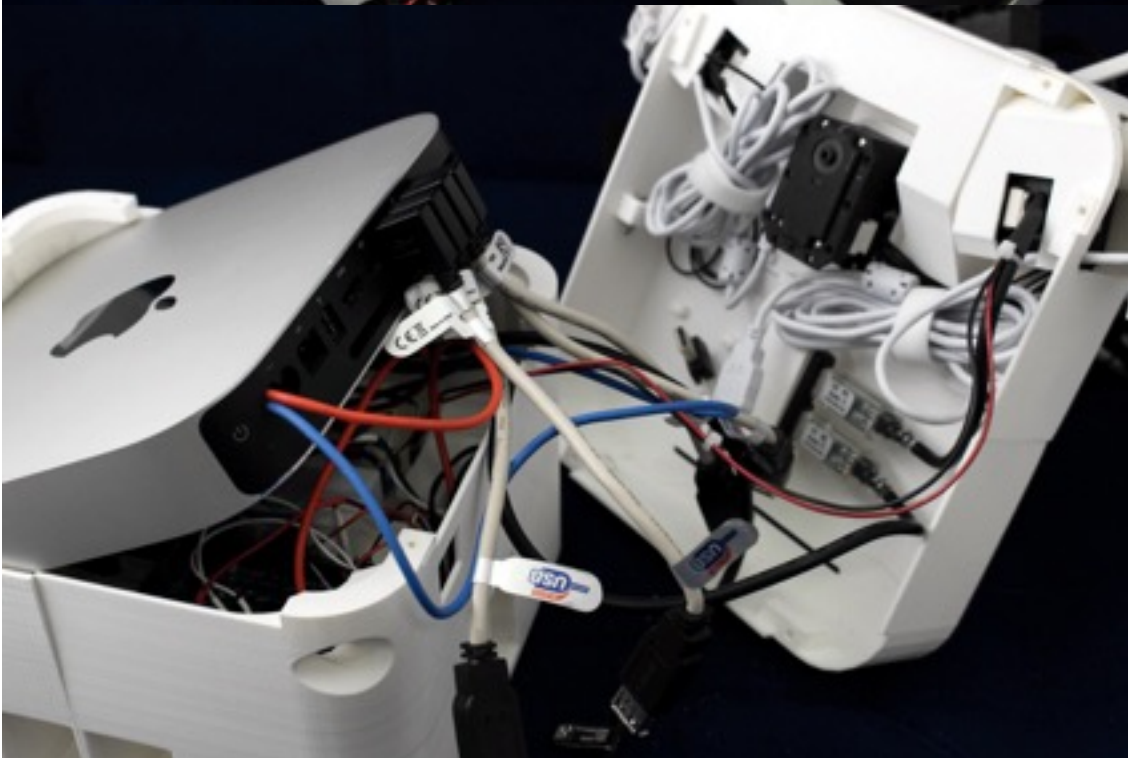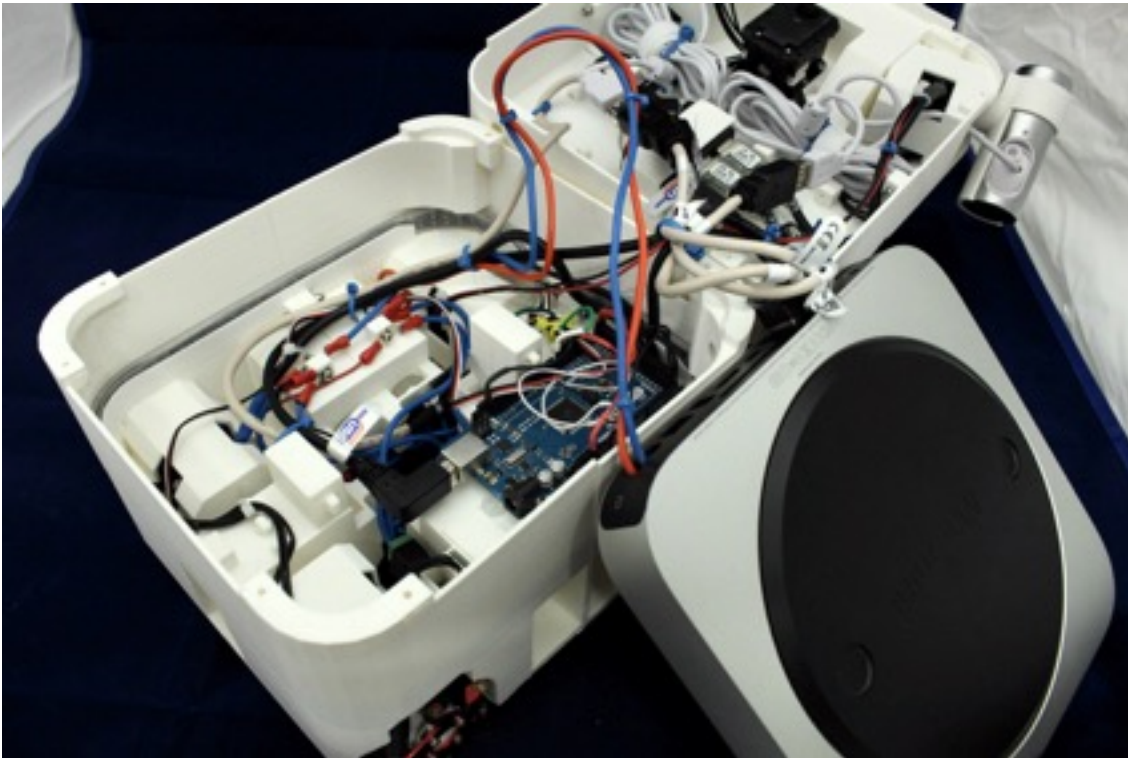
Add four USB extensions cables with 90 degrees connectors. Check all the wiring.

Step 37

Carefully insert the Mac Mini into the robot body.

Step 38

Mount the top part of the robot and insert the batteries.

Step 39
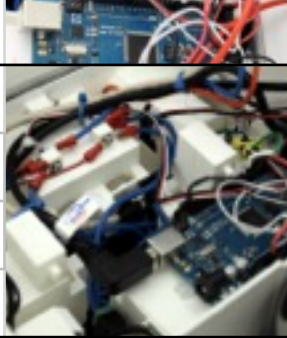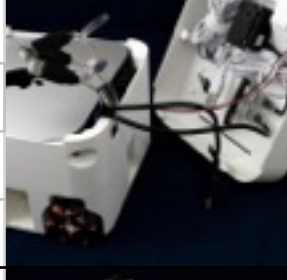
Congratulations, your robot is ready!

References

Balkenius, C., Morén, J., Johansson, B and Johnsson, M. (2010). Ikaros: Building Cognitive Models for Robots. Advanced Engineering Informatics, 24 (1), 40-48

Builder Robot BOM

Column groups: **ROBOTIS Servo** → MX-28 · **Nuts** → M3 Locknut, M2.5 Nut · **Bolts** → M3 x 16, M3 x 20, M2.5 x 6, M2.5 x 16, M2 x 6, M2 x 4, M2.5 x 8, M2.5 x 10, M2.5 x 12 · **Servo Cable** → 140 mm, 250 mm · **Fingertech** → Mecanum wheels · **Camera** → Agent v6 · **Phidgets** → Current sensor, Voltage sensor

Step / Part	Description	#	Part	MX-28	Ball bearing	M3 Locknut	M2.5 Nut	M3 x 16	M3 x 20	M2.5 x 6	M2.5 x 16	M2 x 6	M2 x 4	M2.5 x 8	M2.5 x 10	M2.5 x 12	140 mm	250 mm	Mecanum wheels	LED Strip	Agent v6	Current sensor	Voltage sensor
		#		13	1	12	86	9	3	28	4	20	52	2	18	2	1	2	4	1	2	1	1
1	Put Part A and Part B together with two M3 screws		Part A																				
			Part B																				
		1	M3 x 16					1															
		1	M3 x 20						1														
		2	M3 Locknut			2																	
2	Put together A+B with C using four screews		Part C																				
		2	M3 x 16					2															
		2	M3 x 20						2														
	Put together part D and E		Part D																				
			Part E																				
		4	M3 Locknut			4																	
		6	M3 x 16					6															
		6	M3 Locknuts			6																	
3	Mount 3 servos on part G		Part G																				
		3	MX-28 Servo	3																			
		8	M2.5 x 6							8													
		4	M2.5 x 16								4												
		12	M2.5 Nuts				12																
4	Mount servo on part H		Part H																				
		1	MX-28 Servo	1																			
		4	M2.5 x 6							4													
		4	M2.5 Nuts				4																
5	Mount servo on part I		Part I																				
		1	MX-28 Servo	1																			
		4	M2.5 x 6							4													
		4	M2.5 Nuts				4																
6	Add Part I and J together and mount a servo in part J		Part I																				
			Part J																				
			MX-28 Servo	1																			
		4	M2.5 x 6							4													
		4	M2.5 Nuts				4																
		4	M2 x 6									4											
7	Mount part L and M on part J		Part J																				
			Part L																				
			Part M																				

Builder Robot BOM

Step / Part			#		ROBOTIS Servo MX-28	Ball bearing	M3 Locknut	M2.5 Nut	M3 x 16	M3 x 20	M2.5 x 6	M2.5 x 16	M2 x 6	M2 x 4	M2.5 x 8	M2.5 x 10	M2.5 x 12	Servo Cable 140 mm	250 mm	FIngertech Mecanum wheels	LED Strip	Camera Agent v6	Phidgets Current sensor	Voltage sensor
					13	1	12	86	9	3	28	4	20	52	2	18	2	1	2	4	1	2	1	1
			4	M2 x 4										4										
8		Mount part K on part J		Part K																				
			2	M2.5 x 8											2									
9		Mount parts N on the end of the gripper from step 10	2	Part N																				
10		Mount parts J and the H.	4	M2 x 4										4										
		Bolt on servo horn needs to be removed temporarily																						
11		Mount part H and G.	4	M2 x 4										4										
		Bolt on servo horn needs to be removed temporarily																						
12		Mount servo on part (D)	1	MX-28 Servo	1																			
			4	M2.5 x 6							4													
			4	M2.5 Nuts				4																
13		Place the ball bearing on the top of the part from step 14	1	Axial grooved ball bearing 40 mm, 51204, SKF		1																		
14		Mount part F		Part F																				
		Thread the servo cable through the hole in part F	1	140 mm servo cable														1						
15		Mount the arm (Part G) on part F	8	M2 x 4										8										
16		Mount one part O on each servo	4	MX-28 Servo	4									16										
			16	M2 x 4																				

Builder Robot BOM

Step / Part	Description	#	Part	MX-28	Ball bearing	M3 Locknut	M2.5 Nut	M3 x 16	M3 x 20	M2.5 x 6	M2.5 x 16	M2 x 6	M2 x 4	M2.5 x 8	M2.5 x 10	M2.5 x 12	140 mm	250 mm	Mecanum wheels	LED Strip	Agent v6	Current sensor	Voltage sensor
		#		13	1	12	86	9	3	28	4	20	52	2	18	2	1	2	4	1	2	1	1
17	Mount parts of the wheel holder and part P.	16	M2.5 x 6							16													
		16	M2.5 Nuts				16																
		4	Wheel kits																4				
18	Mount the outer part of the wheels.	16	M2 x 4										16										
		16	M2.5 Nuts				16																
19	Push the servos into the body																						
	Make sure to place the two types of wheels correctly.																						
	Use hot glue to fasten the servos if necessary																						
20	Mount part Q on the servos	2	Part Q																				
	Push the camera into part Q	2	MX-28 Servo	2																			
	Make sure it snaps into the correct orientation	8	M2.5 x 6							8											2		
		2	aGent V6 HD Webcam																		2		
21	Put the servo wires through the holes in the robot	2	250 mm servo cable															2					
	Push the servos into the body of the robot																						
	Make sure there is no support left.																						
22	Set the IDs of the servos																						
23	Cut the LED strip at 74 cm and mount it inside robot	1	Adafruit NeoPixel Digital RGB LED Strip 144 LED - 1m																	1			
24	Power system. Connections to the batteries.	12	M2.5 x 10												12								
	All batteries are connected in parallel	12	M2.5 Nuts				12																
		2	M2.5 x 12													2							
		11	50 mm wires																				
		2	10 mm wires																				
25	Add current sensor and voltage sensor	1	Phidgets 30 Amp Current Sensor AC/DC (1122_0)																			1	
		1	Phidgets Precision Voltage Sensor (1135_1)																				1

Builder Robot BOM

Step / Part			#		ROBOTIS Servo		Nuts		Bolts									Servo Cable		Fingertech	LED Strip	Camera	Phidgets	
					MX-28	Ball bearing	M3 Locknut	M2.5 Nut	M3 x 16	M3 x 20	M2.5 x 6	M2.5 x 16	M2 x 6	M2 x 4	M2.5 x 8	M2.5 x 10	M2.5 x 12	140 mm	250 mm	Mecanum wheels		Agent v6	Current sensor	Voltage sensor
					13	1	12	86	9	3	28	4	20	52	2	18	2	1	2	4	1	2	1	1
26		Connect power to Dynamixel circuit	1	5V Power plug																				
			1	SMPS2Dynamixel Adapter																				
			1	160 mm wire																				
			1	130 mm wire																				
27		Connect the wheel servos	1	60 mm servo wire																				
			1	140 mm servo cable																				
			2	200 mm servo cable																				
		Connect the arm servos	3	140 mm servo cable																				
			2	200 mm servo cable																				
			1	100 mm servo cable																				
28		Mount USB hub	1	Plexgear USB Hub CN-240c																				
29		Make two USB to serial cables	2	FTDI USB-RS485 Converter Cables																				
30		Install the cables (from 29) The motor system is now completely connected.																						
31		Modify the Mac Mini to run on 12 V		Mac Mini. Guides available online																				
32		Connect the Mac Mini to the power system																						
33		Mount the gyro		PhidgetsSpatial 3/3/3 (1044)																				
34		Mount the Arduino		Arduino Mega																				
		Connect voltage and current sonsors																						
		Connect the NeoPixel strip																						

Builder Robot BOM

Step / Part					ROBOTIS Servo	Ball bearing	Nuts		Bolts									Servo Cable		Fingertech	LED Strip	Camera	Phidgets	
					MX-28		M3 Locknut	M2.5 Nut	M3 x 16	M3 x 20	M2.5 x 6	M2.5 x 16	M2 x 6	M2 x 4	M2.5 x 8	M2.5 x 10	M2.5 x 12	140 mm	250 mm	Mecanum wheels		Agent v6	Current sensor	Voltage sensor
			#		13	1	12	86	9	3	28	4	20	52	2	18	2	1	2	4	1	2	1	1
35		Hot glue loose parts (especially the gyro)																						
36		Add four USB extensions cables with 90 degree connectors																						
37		Carefully insert the Mac Mini																						
		Make sure the USB extension cables are oriented upwards																						
38		Mount the top of the robot																						
		Use six M2.5 screws	6	M2.5 x 10												6								
			6	M2.5 Nuts				6																
		Insert the batteries	6	12 V battery pack (10 AA batteries)																				
39		Congratualtions, your robot is ready!																						
			297		13	1	12	86	9	3	28	4	20	52	2	18	2	1	2	4	1	2	1	1

Dynamical MX-28	13	220	2 860	
Mac Mini	1	499	499	
Ball Bearing	1	18	18	
Arduino Mega	1	35	35	
mecum wheels	1	75	75	
Agent v6 Cameras	2	70	140	
USB->Serial Adaters	2	30	60	
Battery packs	6	80	480	
Sensors	1	50	50	
Cables			0	
USB Hub		15	0	
Plastic			0	
Time….			0	
			4 217	