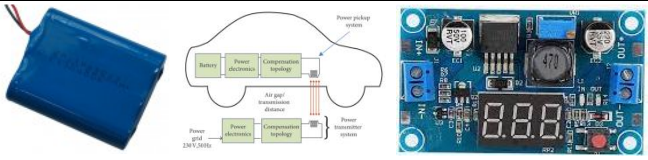
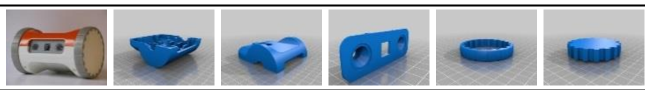
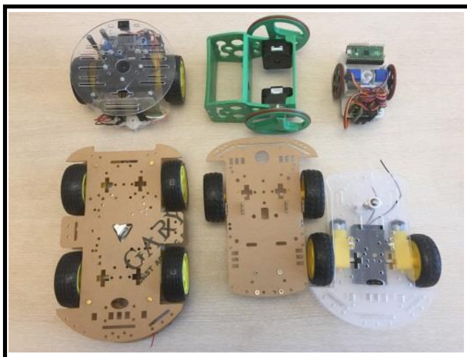
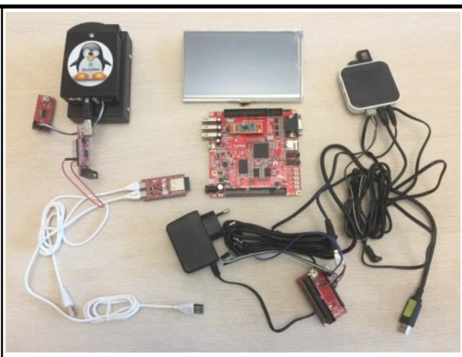
Own implementation of open source intelligent robot – startup design notes

Target hardware and software to implement the basic ideas of multi-variant series of robots for usage in STEAM education:

Layer	Variants	Hardware	Software	Available staff
Development	User's desktops, laptops and group server	Multicore dual CPU Xeon and i5/i7 based	Linux, Windows, Gitlab, VM staff	
Environment Simulation	Vision and sound sources, Environment simulator	Lime2 Server with SSD, NEO Core Starter Kit, Video display or projector	Linux, Debian, Armbian, C/C++, Javascript, Python, HTML 5	
Environment Interface and Interaction Control	Video cameras & emotions display, Stereo microphone & speaker, Accelerometer, Gyroscope, Compass etc.	Raspberry Pi 5, Pi Zero 2 W, Pi Pico, ESP32, ESP32-S3, Video cameras, SPI / HDMI displays	Linux, Debian, Armbian, C/C++, Javascript, Python, HTML 5	
Motion and body Control	Stepper, servo or dc motors (geared or direct drive), Digital encoders	Raspberry Pi Pico, Motor drivers	RP2040 PIO based stepper motor control	
Power	LiPo batteries, wireless chargers, dc-dc convertors			
Skeleton	Silicon cover, 3D printed modules			

Ready to play with:


3D printed and laser cut chassis


Allwinner A20 / A13 and ESP32-S3 staff


Allwinner H3 staff


Motor, driver, power and sensor staff


Pi 5, Zero 2 W, Pico, ESP32-CAM etc.


Pi Pico and ESP32 experimental staff

Emotional and human like functionality of the robot

Human like activities

Balancing

Communicating

Dancing

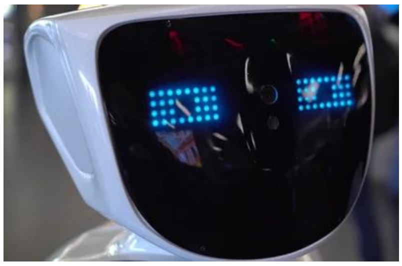
Drawing

Path following

Show emotions

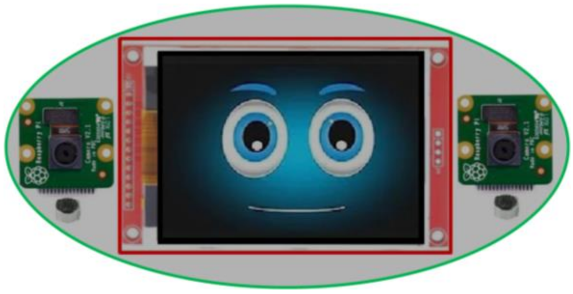






Preferable choice for head look and possible face simulations on a TFT display

Face variants with stereo audio & vision:



Combination of 3.2" TFT SPI display, dual ESP32-CAM modules, Raspberry Pi Zero 2 W and Pi Pico

- Face size: 140 x 55 mm (rounded rectangle in green);
- 3.2" TFT SPI display size: 90 x 54 mm (picture);
- 2MP ESP32-CAM module size: 24 x 40 mm (pictures);
- Raspberry Pi Pico size: 51 x 21 mm (not visible);
- Raspberry Pi Zero 2 W size: 65 x 30mm (not visible).

Combination of 3.2" TFT SPI display, dual Raspberry Pi Camera Module 2, Raspberry Pi 5 and Pi Pico

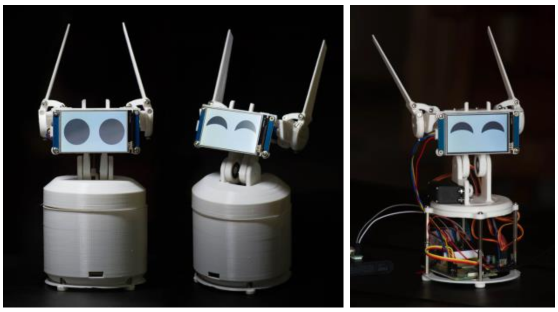
- Face size: 140 x 70 mm (ellipse in green);
- 3.2" TFT SPI display size: 90 x 54 mm (central picture);
- 8MP Raspberry Pi Camera ver. 2 size: 24 x 25 mm (picture);
- Raspberry Pi Pico size: 51 x 21 mm (not visible);
- Raspberry Pi 5 size: 85 x 56mm (rectangle in red).

Notes:

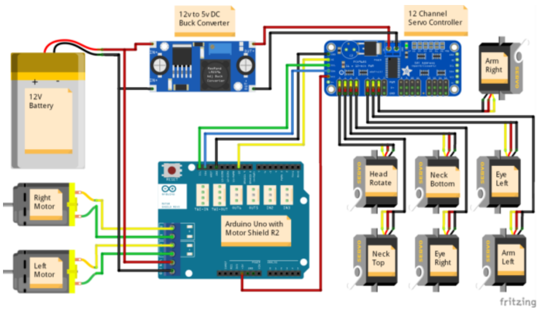
- Raspberry Pi Pico will control TFT SPI display and will generate emotional animation;
- Second Raspberry Pi Pico will control motors and robot motion and positioning;
- Raspberry Pi 5 or Pi Zero 2 W will control head/eyes motion, audio and video streams and environment interactions;
- Lime2 Server or NEO Core Starter Kit (both with SSD) will be used as a base station and environment simulator.

Some useful links to open source emotional robots:

Awesome-social-robots: A list of resources, ideas, and projects to create Open Source Social Robots;
Direct Digital Synthesis thanks to V. Hunter Adams (vha3@cornell.edu);
VoiceGPT is a voice assistant that leverages the powerful ChatGPT chatbot to answer your questions;
Snowboy Hotword Detection: DNN based hot word and wake word detection toolkit (model generation included).

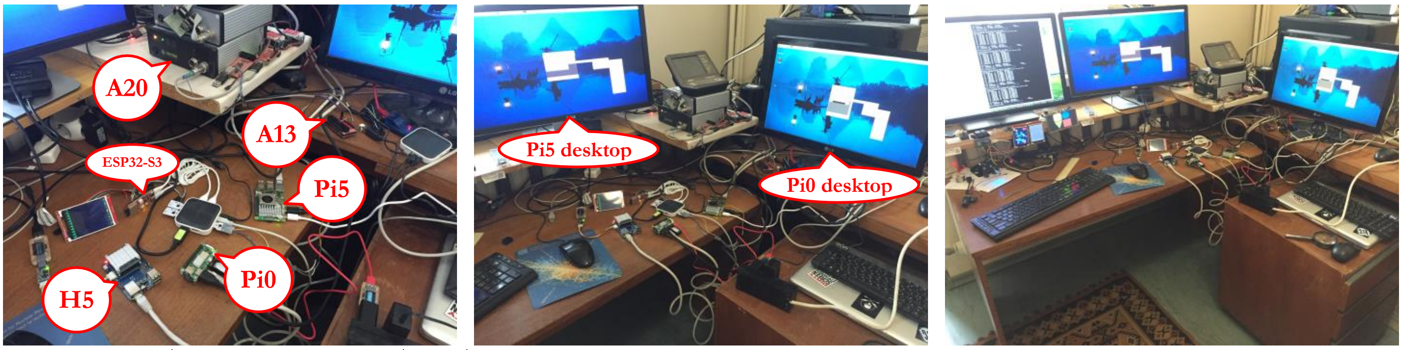


EWON Raspberry Pi Powered Home Robot
on Instructables and Thingiverse;



3D Printed WALL·E

Performance measurement of the available Linux boxes



Raspberry Pi 5 / Zero, Allwinner H5 /A20 / A13 Linux boxes and ESP32-S3 setup

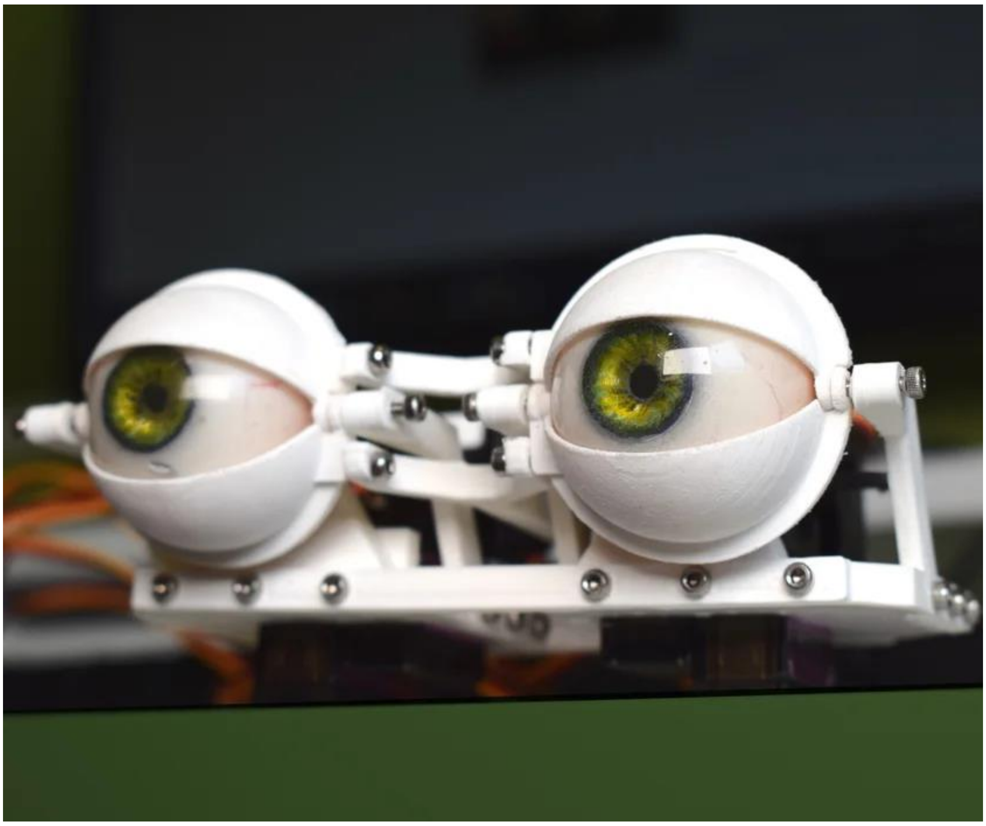
Raspberry Pi 5 Model B, 4GB (8GB is also available)	**163x**
Hardware	Broadcom BCM2712 quad-core 64-bit Arm Cortex A76 CPU up to 2.4GHz; VideoCore VII GPU with Dual 4Kp60 HDMI display output; 4GB SDRAM; 32GB SD card; Dual-band 802.11ac Wi-Fi; Bluetooth 5.0 / BLE; 1Gb Ethernet; Dell P2415Q display on HDMI0 @ 1600x1200 (4k is supported); Active Cooler; 27W Power supply
Image maker / file	Raspberry Pi Imager / 2023-12-05-raspios-bookworm-arm64-full.img.xz
uname –a (after upgrade)	Linux rp5 6.1.0-rpi8-rpi-2712 #1 SMP PREEMPT Debian 1:6.1.73-1+rpt1 (2024-01-25) aarch64 GNU/Linux
lscpu	Architecture: aarch64; CPU op-mode(s): 32-bit, 64-bit; Byte Order: Little Endian; CPU(s): 4; Vendor ID: ARM; Model name: Cortex-A76; Thread(s) per core: 1; Core(s) per cluster: 4; CPU max: 2.4GHz; CPU min: 1.5GHz; BogoMIPS: **108.0**
sysbench cpu --threads=4 run	CPU speed: events per second: **10,920.28**; Latency (ms): **min: 0.36; avg: 0.37; max: 1.06; 95th percentile: 0.37**
iperf3 -c 192.168.1.178	10.00 sec 924 MBytes **775 Mbits/sec** 10 sender; 10.00 sec 923 MBytes **774 Mbits/sec** receiver
Geekbench 6	Raspberry Pi 5 Model B Rev 1.0 ARM ARMv8 2.4GHz (1 cores, 4 threads) | Linux | AArch64 | **799** | **1635**
Raspberry Pi Zero 2 W (passive cooling will be a problem in a box)	**29x**
Hardware	Custom SIP RP3A0 quad-core 64-bit ARM Cortex-A53 CPU up to 1GHz; GPU with Dual 4Kp60 HDMI® display output; 512MB SDRAM; 32GB SD card; 2.4GHz 802.11 b/g/n Wi-Fi; Bluetooth 4.2 / BLE; USB hub with 100Mb Ethernet; LG W2261VP display on HDMI @ 1920x1080 (HD is supported); Passive Cooler; 10W Power supply
Image maker / file	Raspberry Pi Imager / 2023-12-05-raspios-bookworm-arm64-full.img.xz
uname –a (after upgrade)	Linux rp0 6.1.0-rpi8-rpi-v8 #1 SMP PREEMPT Debian 1:6.1.73-1+rpt1 (2024-01-25) aarch64 GNU/Linux
lscpu	Architecture: aarch64; CPU op-mode(s): 32-bit, 64-bit; Byte Order: Little Endian; CPU(s): 4; Vendor ID: ARM; Model name: Cortex-A53; Thread(s) per core: 1; Core(s) per cluster: 4; CPU max: 1GHz; CPU min: 600MHz; BogoMIPS: **38.4**
sysbench cpu --threads=4 run	CPU speed: events per second: **1,956.53**; Latency (ms): **min: 2.03; avg: 2.04; max: 3.18; 95th percentile: 2.03**
iperf3 -c 192.168.1.178	10.00 sec 113 MBytes **94.6 Mbits/sec** 10 sender; 10.00 sec 112 MBytes **94.2 Mbits/sec** receiver
NanoPi NEO Core-LTS (Starter Kit)	**3x**
Hardware	Allwinner H3 quad-core ARM Cortex-A7 CPU up to 1.2GHz; 512MB SDRAM; 4GB SD card; USB hub with 100Mb Ethernet; Passive Cooler; USB powered
Image maker / file	USBImager v.1.0.10 / Armbian_23.11.1_Nanopineo_bookworm_current_6.1.63.img.xz
uname –a (after upgrade)	Linux nanopineo 6.1.63-current-sunxi #1 SMP Mon Nov 20 10:52:19 UTC 2023 armv7l GNU/Linu
lscpu	Architecture: arm7l; Byte Order: Little Endian; CPU(s): 4; Vendor ID: ARM; Model name: Cortex-A7; Thread(s) per core: 1; Core(s) per socket: 4; CPU max: 1.296GHz; CPU min: 480MHz; BogoMIPS: **48.0**
sysbench cpu --threads=4 run	CPU speed: events per second: **198.02**; Latency (ms): **min: 20.01; avg: 20.16; max: 54.44; 95th percentile: 20.00**
iperf3 -c 192.168.1.178	10.00 sec 113 MBytes **94.6 Mbits/sec** 10 sender; 10.00 sec 112 MBytes **94.2 Mbits/sec** receiver
A20-OLinuXino-LIME-8GB eMMC (Own box – old setup)	**1x**
Hardware	Allwinner A20 dual-core ARM Cortex-A7 CPU up to 1GHz; Mali 400 GPU with HDMI output (HD is supported); 1GB DDR3 RAM; 8GB eMMC; 480GB SATA SSD; 1Gb Ethernet; Passive Cooler; 15W Power supply
Image maker / file	Win32DiskImager v.1.0 / Armbian_5.27_Lime2-emmc_Debian_jessie_next_4.10.5.img
uname -a (own build)	Linux egpr 4.10.5-sunxi #4 SMP Wed Mar 22 23:38:40 EET 2017 armv7l GNU/Linu
lscpu	Architecture: arm7l; Byte Order: Little Endian; CPU(s): 2; Thread(s) per core: 1; Core(s) per socket: 2; Model name: ARMv7 Processor rev 4 (v7l); CPU max: 960MHz; CPU min: 144MHz; BogoMIPS: **27.78**
sysbench cpu --threads=2 run	CPU speed: events per second: **66.93**; Latency (ms): **min: 29.23; avg: 29.87; max: 59.99; 95th percentile: 31.20**
iperf3 -c 192.168.1.178	10.00 sec 112 MBytes **94.3 Mbits/sec** 10 sender; 10.00 sec 112 MBytes **94.0 Mbits/sec** receiver
A13-SOM-512 & A13-SOM-WIFI-4GB (modified)	**0.55x**
Hardware	Allwinner A13 ARM Cortex-A8 CPU up to 1GHz; 512MB DDR3 RAM; 4GB NAND Flash; USB hub; 32GB USB flash disk; USB WiFi; 100Mb Ethernet; No Cooler; USB powered
Image maker / file	Win32DiskImager v.1.0 / A13-OLinuXino-jessie-base-20230217-181328.img.7z
cat /proc/version	Linux version 5.10.105-olimex Debian 8.3.0-2 #181328 SMP Fri Feb 17 18:14:43 UTC 2023
lscpu	Architecture: arm7l; Byte Order: Little Endian; CPU(s): 1; Thread(s) per core: 1; Core(s) per socket: 1; Vendor ID: ARM; Model name: Cortex-A8; CPU max: 1GHz; CPU min: 432MHz
sysbench cpu --threads=2 run	CPU speed: events per second: **36.72**; Latency (ms): **min: 26.82; avg: 27.19; max: 45.54; 95th percentile: 28.16**
iperf3 -c 192.168.1.178	10.00 sec 112 MBytes **94.2 Mbits/sec** 10 sender; 10.00 sec 112 MBytes **93.8 Mbits/sec** receiver

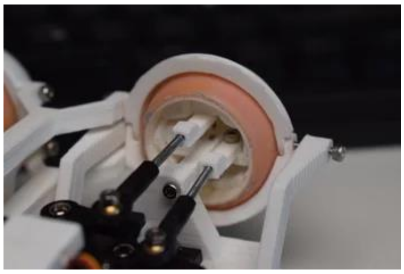
Notes: iPerf3 server is running on 4-core i7 Windows 7 PC, 1Gb Ethernet infrastructure;
ESP32-S3 is not running Linux and no performance tests were done.

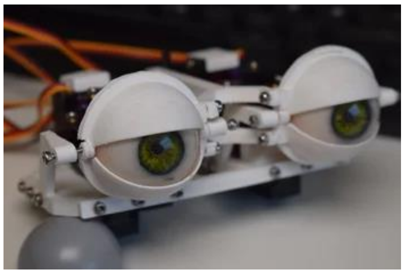
Compact and Robust 3D Printed Animatronic Eye Mechanism

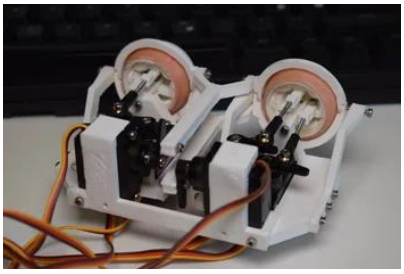
Main start up points:

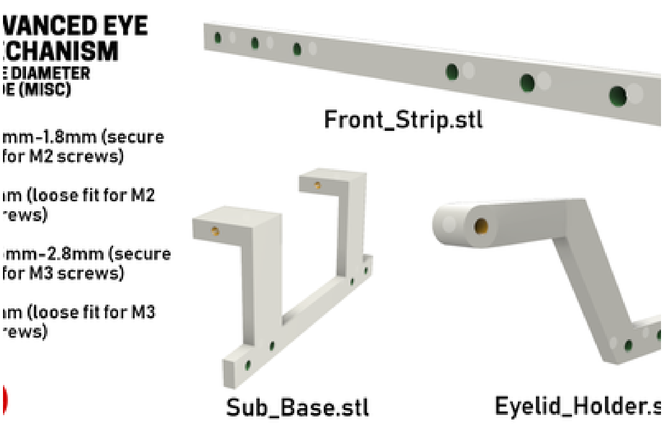
- http://www.nilheim.co.uk/latest-projects-and-blog/compact-and-robust-3d-printed-animatronic-eye-mechanism
- https://www.instructables.com/DIY-Compact-3D-Printed-Animatronic-Eye-Mechanism/

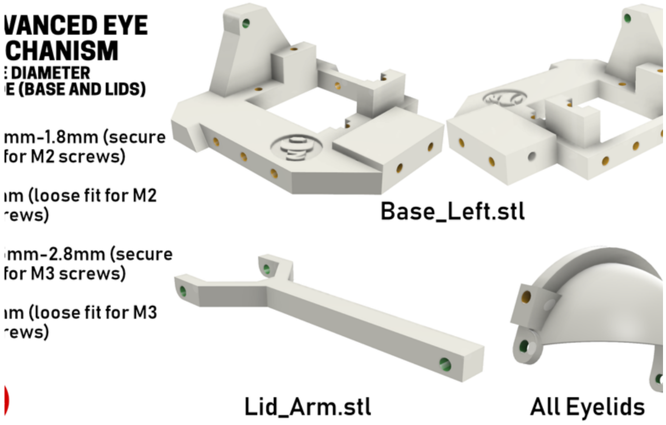


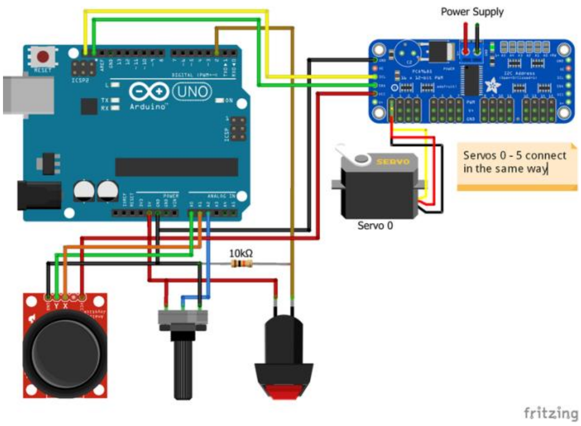


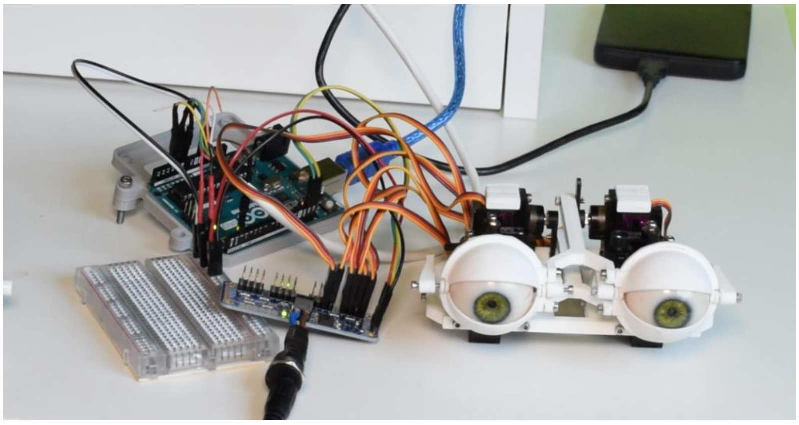






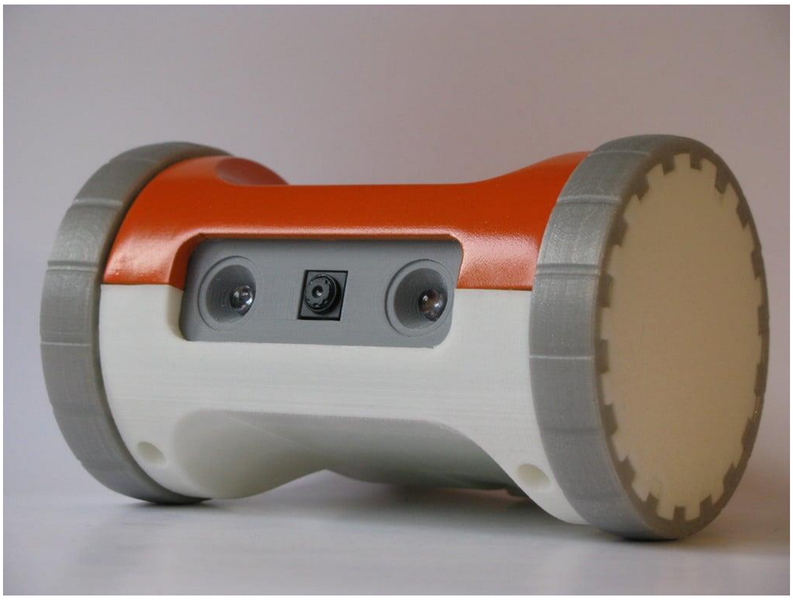


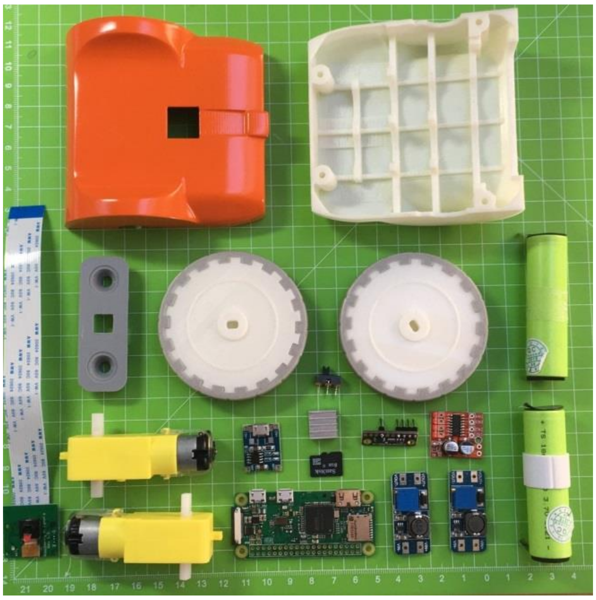


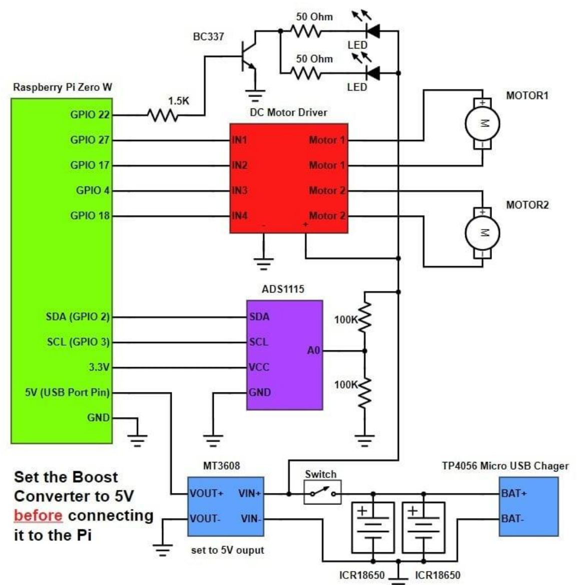


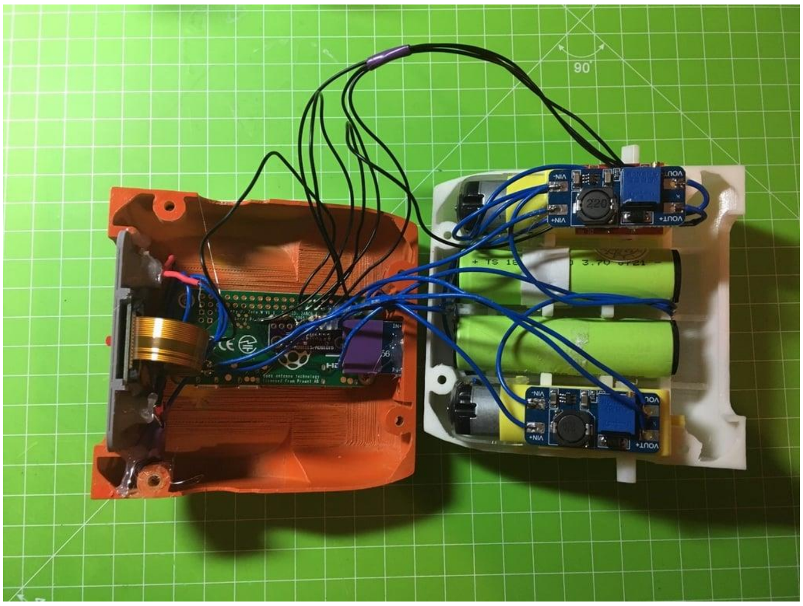
ZeroBot Pro – Raspberry FPV Robot

Main start up point – [ZeroBot Pro – Raspberry FPV Robot]()



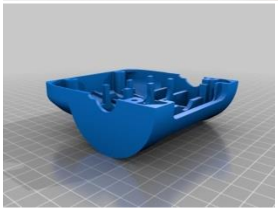
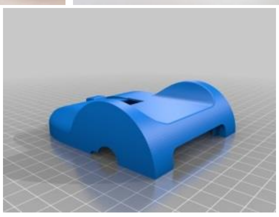
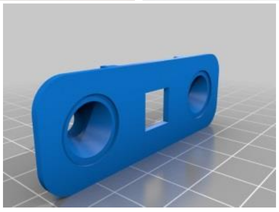
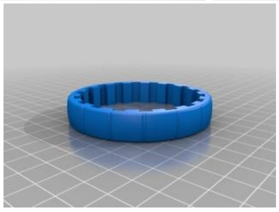
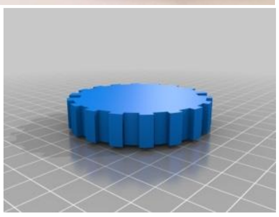






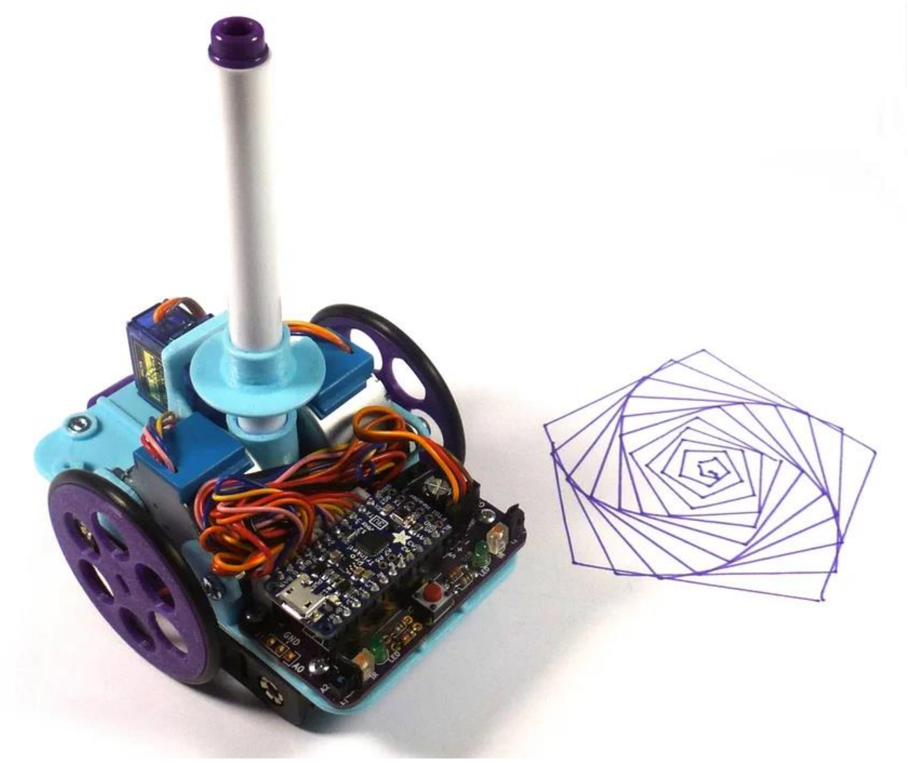
The project is described on: https://hackaday.io/project/25092/instructions



Open Source Intelligent Robot (OSIR)

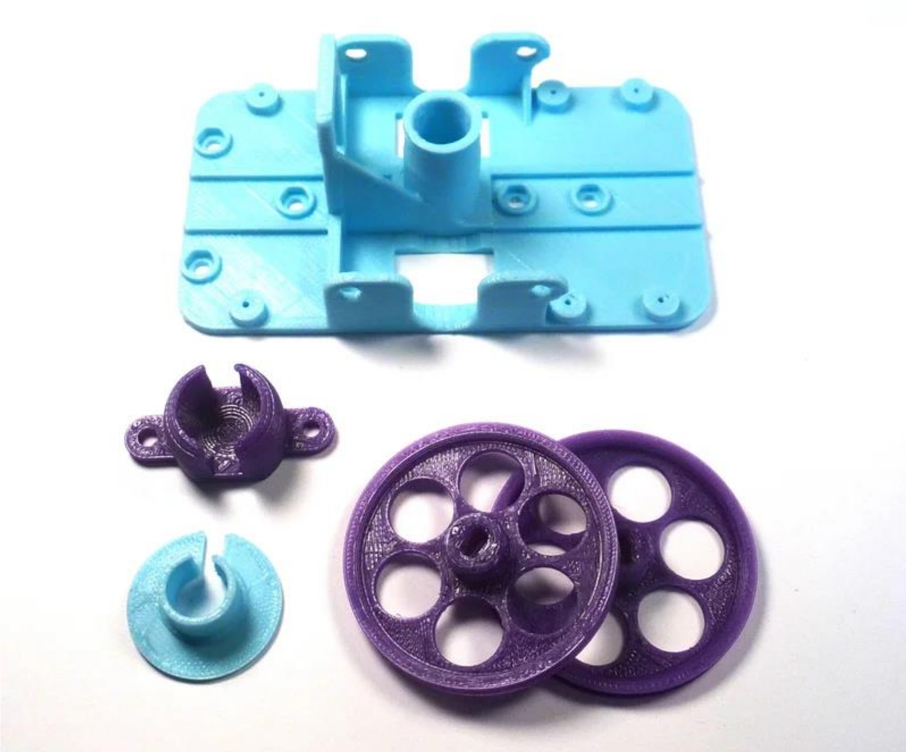
Main start up point – Open Source Turtle Robot (OSTR)



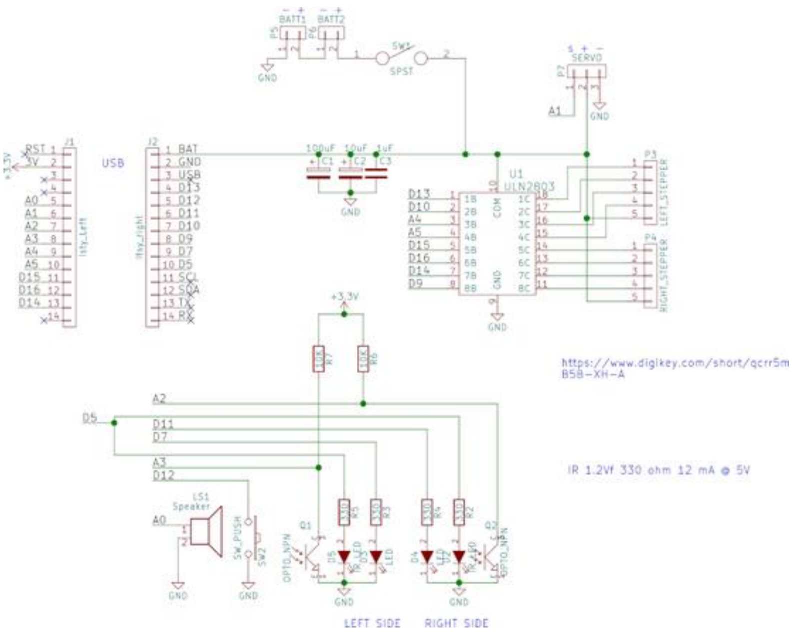
The project is described on: https://www.instructables.com/OSTR/

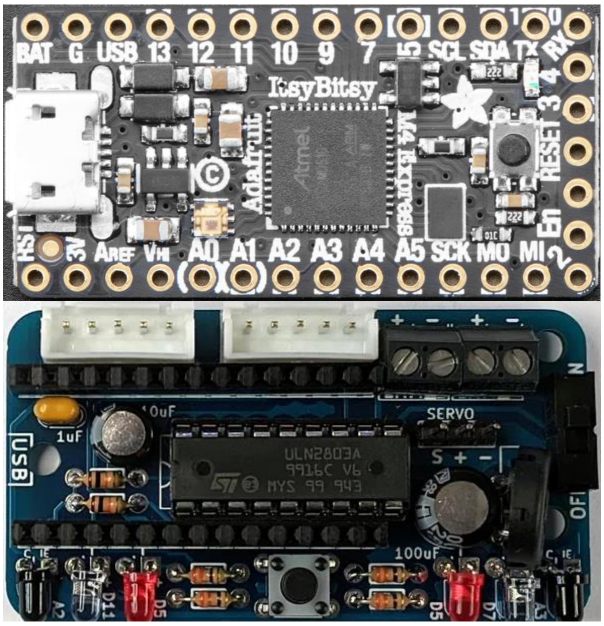
Electronics:	
Turtle Robot Board Kit	Will be changed, TFT SPI 3.2"Display
Adafruit ItsyBitsy Microcontroller (M4 recommended)	AVR32D48 and ESP32 module or Linux box
USB micro cable	For programming only
Electromechanical:	
2 Geared 5V 28byj Steppers	
1 Micro servo	
2 2 x AA Battery Holders	No holder
4 AA batteries	BATTERY-LIPO4400mAh
3D Parts:	
Chassis	
2 wheels	
Caster	
Hardware:	
M3 screws and nuts	
5/8 steel bearing	
2 Dash 223 O-rings	
Software:	
Main staff	Web server and client, Web Sockets, JS control application, CircuitPython runtime
Languages	C/C++, Python, HTML 5, JavaScript
Libraries	Turtle, Adafruit CircuitPython Bundle

Main electromechanical and 3D parts from OSTR:



Turtle Robot Board Kit from OSTR:

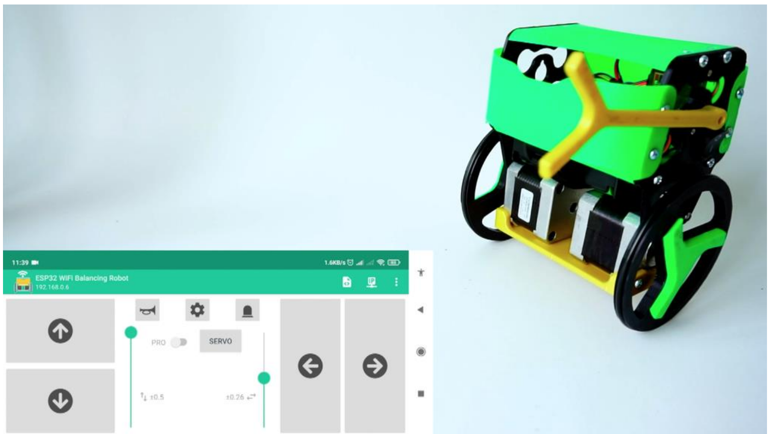


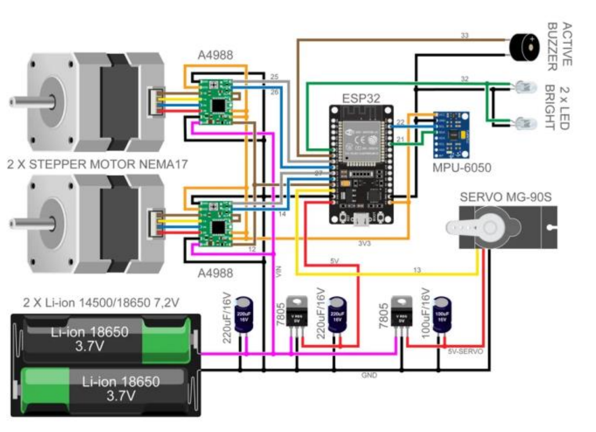


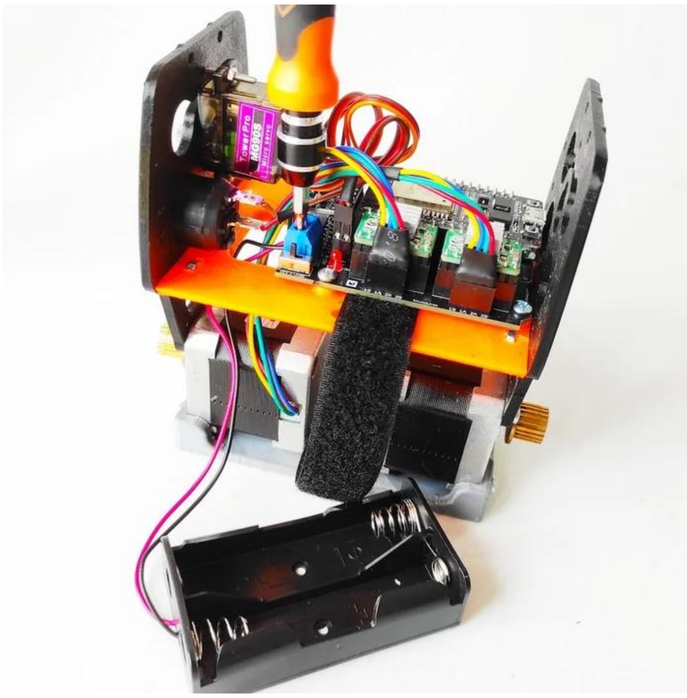
Open Source Turtle Robot (OSTR)

https://www.instructables.com/OSTR/,

https://github.com/aspro648/OSTR/tree/master



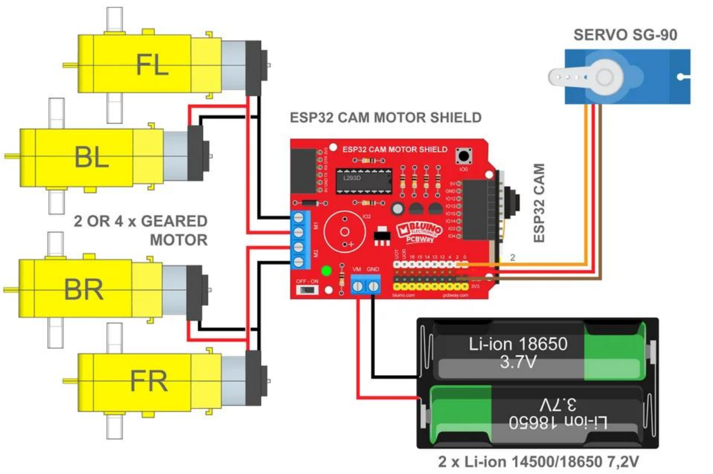


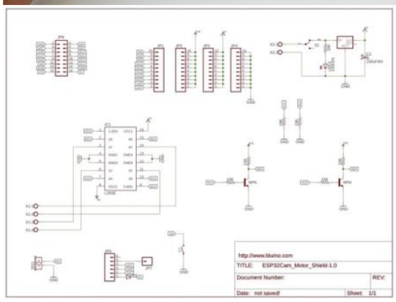


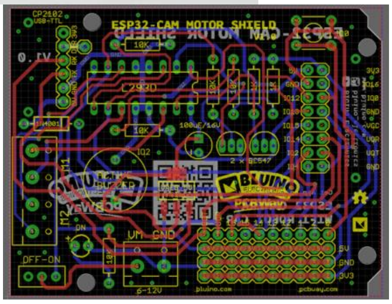
DIY ESP32 Wifi Self Balancing Robot and Android Application

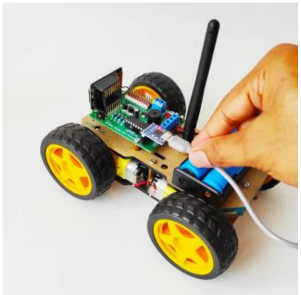
- https://www.instructables.com/DIY-ESP32-Wifi-Self-Balancing-Robot-B-Robot-ESP32-/,
- https://github.com/bluino/esp32_wifi_balancing_robot,
- https://play.google.com/store/apps/details?id=com.bluino.esp32wifibalancingrobot&pli=1

Wifi Camera Robot Car based on ESP32 CAM



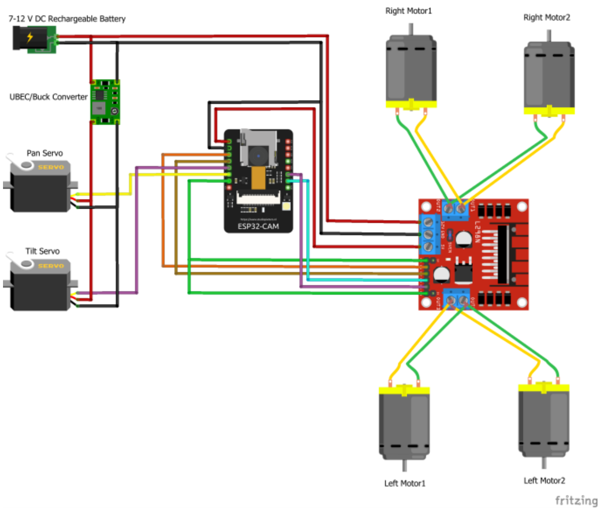


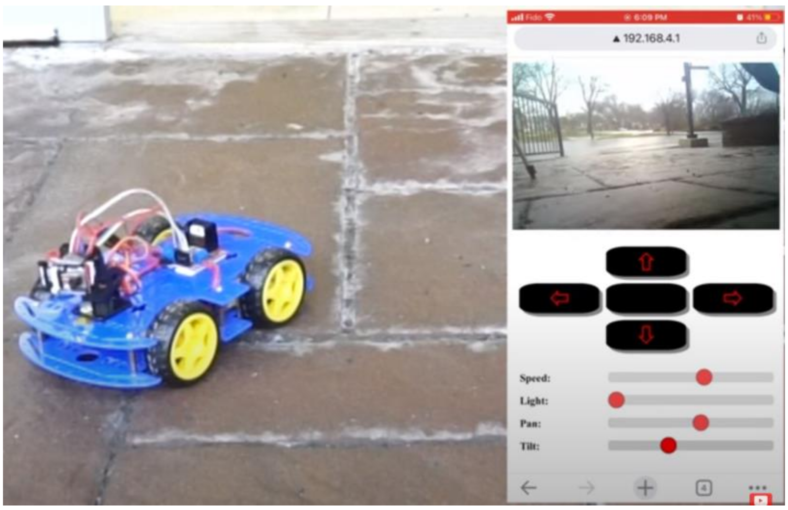




DIY ESP32 Camera Motor Shield project:

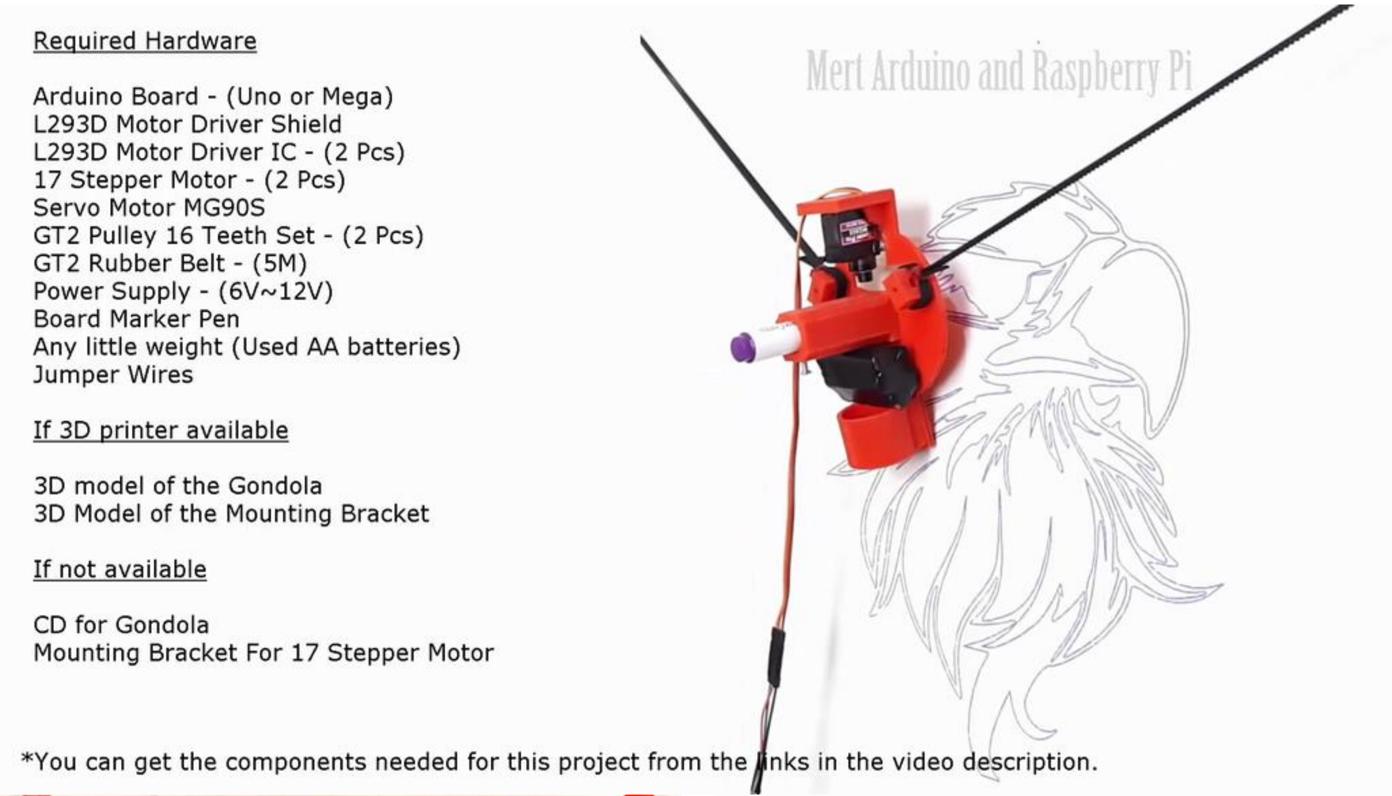
- DIY ESP32 Camera Motor Shield - Wifi Camera Robot Car
- ESP32-Cam Motor Driver Shield L293D
- Android App: ESP32 Camera Wifi Robot Car

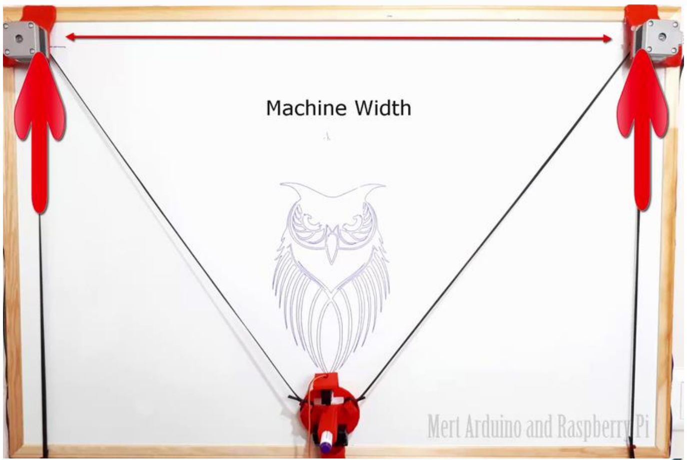


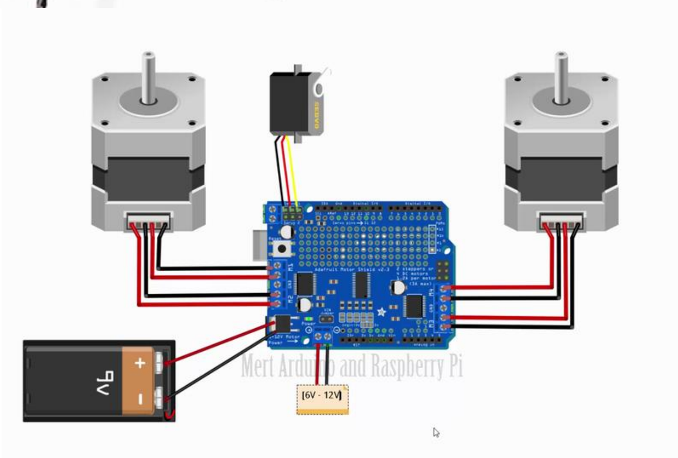


Camera Car with Pan Tilt Control and ESP32Cam

- YouTube video
- Github project



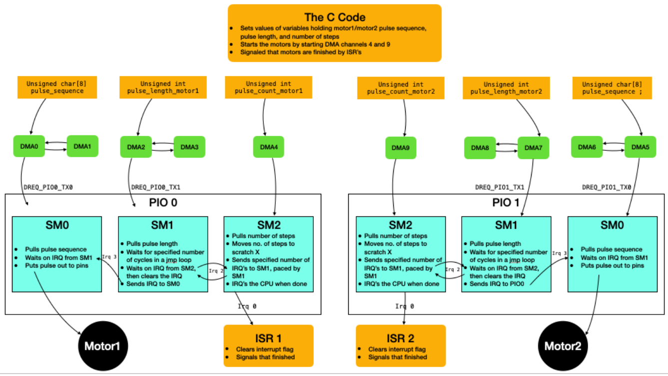




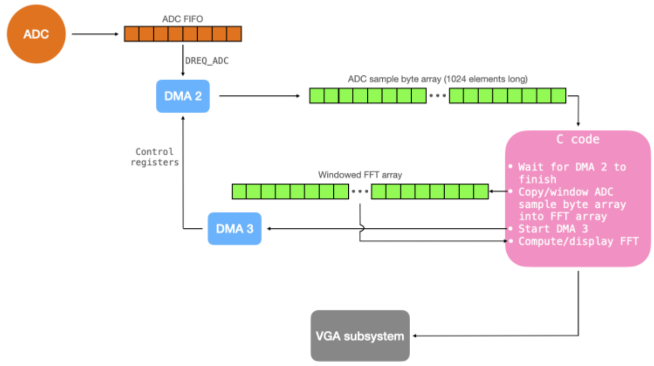
Low-Budget XY Plotter Drawing Robot Board

- https://www.instructables.com/XY-Plotter-Drawing-Robot-Arduino-Polargraph/
- https://www.instructables.com/MXY-Board-Low-Budget-XY-Plotter-Drawing-Robot-Boar/
- https://www.pcbway.com/project/shareproject/mXY_Board___Low_Budget_XY_Plotter_Drawing_Robot_Board.html

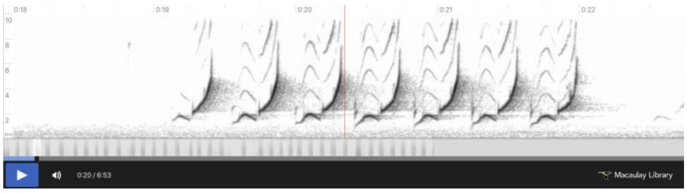
Some ideas for internal design thanks to Van Hunter Adams (vha3@cornell.edu)



PIO-Based Stepper Motor Driver for RP2040
https://github.com/vha3/Hunter-Adams-RP2040-Demos/tree/master/Stepper_Motors
https://vanhunteradams.com/Pico/Steppers/Lorenz.html
https://vanhunteradams.com/DDS/DDS.html



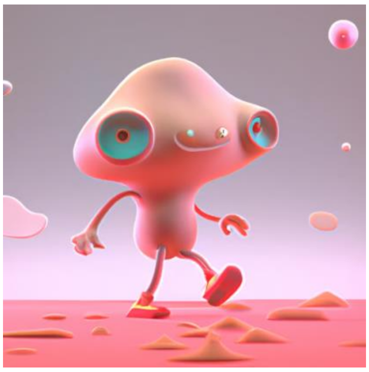
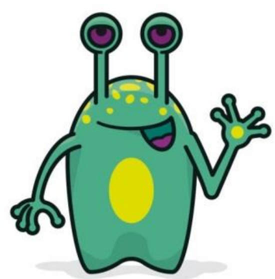
Real-time Audio FFT to VGA Display with RP2040 (Raspberry Pi Pico)
https://vanhunteradams.com/Pico/VGA/FFT.html

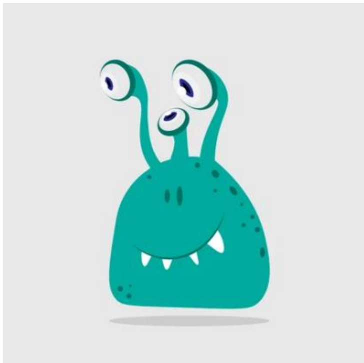


Direct Digital Synthesis
https://vanhunteradams.com/DDS/DDS.html
https://vanhunteradams.com/Pico/Cricket/Crickets.html
https://github.com/vha3/Hunter-Adams-RP2040-Demos/tree/master/Audio

Pulse-Width Modulation Demonstrations
https://github.com/vha3/Hunter-Adams-RP2040-Demos/tree/master/PWM
https://vanhunteradams.com/Pico/ReactionWheel/HBridgeCircuit.html

Some ideas for external design



Portrait / landscape body with TFT display, 2 wheels mechanics, 1-3 eye like movable cameras, 4-pen drawing set etc.

Some ideas for the web interface and main staff

- Will be able to balance, dance, draw, show emotions, follow visual paths and audio commands and other human activities;
- Will use http(s) protocol over direct (WiFi AP) or indirect (WiFi STA via local router) connection with control application running into the user's web browser (modern versions);
- Robot can be programmed by the following methods:
    - Using the open source firmware code;
    - Visual programming by blocks with translation to Python and/or JavaScript script and running in the simulator;
    - Programming with built-in JavaScript interpreter and/or Python runtime and running in the simulator;
    - Loading of vector images with translation to JavaScript and/or Python script and running in the simulator;
- The robot will have:
    - 2 microphones, 2 loudspeakers and stereo amplifier with possibility to talk via connection;
    - a camera for watching the video in user's control application;
    - the microphones and camera can be used for robot control;
    - home station with wireless battery charger and "go-to-home" mode;
- In advanced version the robot will have:
    - built-in Linux box with WiFi and directly connected to internal MCU;
    - stereo camera connected to the Linux box for stereo vision;
- All versions will have TFT display for emotions showing controlling with separate MCU.