ABSTRACT

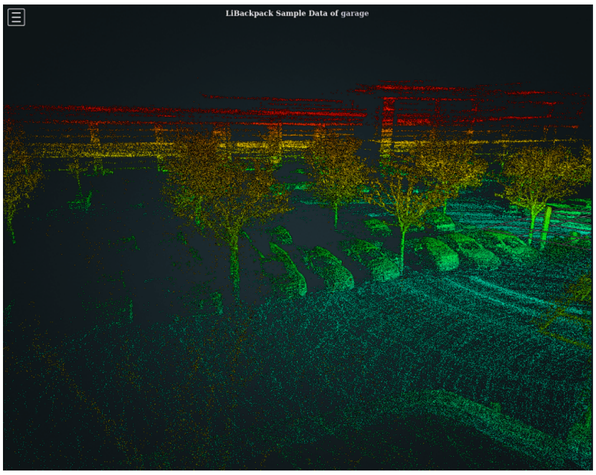
LIDAR and Camera Object Detection is a project on which i integrated electronics and machine learning algorithms. We learned how to program microcontrollers and development boards. This project uses LIDAR to measure accurate distance using TOF or time of flight algorithm of an object in front of it. We also use a camera to detect the object using TensorFlow machine learning algorithm. The LIDAR and camera is therefore integrated on a single package using raspberry PI. The LIDAR and camera is attached to a servo that continuously sweeps 180 degrees several times per second. This project is intended to be applied on applications such as autonomous driving ,military applications, robots etc. for the ahead lying robotics era.

INTRODUCTION

LIDAR & Camera Object Detection

LIDAR is a surveying method that measures distance to a target by illuminating the target with laser light and measuring the reflected light with a sensor. Differences in laser return times and wavelengths can then be used measure distance of the target. The name LIDAR stands for light detection and ranging. Camera can be used to identify the target using TensorFlow Ai Algorithm. We can train the algorithm to identify our required objects for applications like military surveillance and autonomous driving etc.

Project Description/Introduction



LIDAR o/p Data

Our project is based on a LIDAR module and Webcam on a servo motor. We are using Raspberry PI 3B+ as its brains to control the required detection and ranging. LIDAR is given as input to the Raspberry PI using serial min UART pins and a python script spins the servo 180 degrees several times reading the distance to the target and outputs it to a terminal. The servo turns the LIDAR module and the webcam. TensorFlow Ai API is used for object detection and training. We trained the algorithm to detect specific objects. The LIDAR's precise range of the target along with the identification of the object using Tensoflow is outputted into a windows on Raspberry PI OS. Currently autonomous cars and military drones, unmanned vehicles use IR cameras and thermal imagery technology along with ranging technologies like SONAR etc. Such solutions are expensive, less accurate, less precise and short ranged. With our LIDAR-Camera implementation we intend to solve these problems and open new doors for such applications

Why chose LIDAR over other alternative ranging systems?

What Is LIDAR?

LIDAR is also known as Light Imaging Detection and Ranging. It is a technology which detects objects on the surface, as well as their size and exact disposition. LIDAR appeared after RADAR and SONAR, and it uses laser light pulses to scan the environment, as opposed to radio or sound waves.

The military invented the LIDAR technology more than 45 years ago for measuring distance in space. Now, the LIDAR system design is quite compact and allows the industry to apply this technology for new purposes. A device which uses LIDAR technology is also often called the same; it is a scanner that can create a digital copy of any physical object and that can save more time as compared to starting from scratch with a drawing.

How LIDAR Works?

An algorithm of LIDAR functioning:

- Laser signals are emitted;
- Laser signals reach an obstacle;
- Signal reflects from the obstacle;
- Signal returns to the receiver; and then
- A laser pulse is registered.

The device emits laser pulses which move outwards in various directions until the signals reach an object, and then reflect and return to the receiver. This is the same principle LIDAR uses, except LIDAR emits sound waves. With LIDAR, the light is 1,000,000 times faster than the sound. An example is during a hurricane with lighting - at first, we see the lightning and only hear the sound a couple of seconds later. Such high speed allows the device to receive data from a tremendous number of laser pulses every second. It means information is updated more frequently and, as a result, more precise data is received.

An inner processor saves each reflection point of a laser and generates a 3D image of the environment. Such working principles allow us to create precise maps using a LIDAR installed on board a plane, for example. Furthermore, the same processor can calculate the distance between a detected object and a LIDAR receiver by using a simple school formula where laser pulse speed and reflection time are known, and we then calculate the distance a laser pulse travels along. This possibility found its application in the automotive industry and thrives there: all driverless cars use on board LIDARS to scan their surroundings.

LIDAR vs Alternatives.

1)LIDAR vs Radar

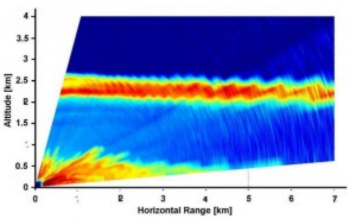
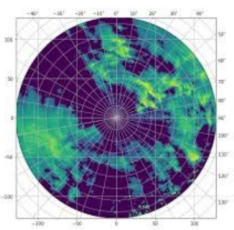
What is Radar?

Radar is a detection system that uses radio waves to determine the range, angle, or velocity of objects. It can be used to detect aircraft, ships, spacecraft, weather formations, and terrain. A radar system consists of a transmitter producing electromagnetic waves in the radio or microwaves domain, a transmitting antenna, a receiving antenna, a receiver and processor to determine properties of the objects. Radio waves from the transmitter reflect off the object and return to the receiver, giving information about the object's location and speed.

Working

The radar transmits a focused pulse of microwave energy (just like a microwave oven or a cell phone, but stronger) at an object, most likely a cloud. Part of this beam of energy bounces back and is measured by the radar, providing information about the object. Radar can measure precipitation size, quantity, speed and direction of movement, within about 100-mile radius of its location.

1)LIDAR vs Radar

LIDAR	*Radar*
• LIDAR which is short for Light Detection and Ranging uses a laser that is emitted and then received back in the sensor. • Uses Light (EM Waves). • Varying optical and infrared spectra with short wavelengths. • LIDAR using ToF (Time Of Flight) needs high speed electronics that cost more • More Data. • Higher Accuracy. • Higher o/p Resolution. • Lower Range. • Can't be used on all environments. 	• RADAR which is short for Radio Detection and Ranging uses radio waves to compute velocity, and/or range to an object. • Uses RF waves. • Large Spectrum/Bandwidth. • LIDAR sensors needs CCD receivers, optics, motors, and lasers to generate and receive the waves used. RADAR only needs some stationary antennas. • Less o/p data. • Lower Accuracy. • Higher Range. • Can be used on foggy/smog days. 

2)LIDAR vs Sonar

What is Sonar?

Sonar stands for sound navigation and ranging. This is an object detection technology that uses sound waves to detect objects in the environment. Among a LIDAR, radar, and sonar, the latter system is the oldest. Self-driving vehicles like Tesla use active sonars which, unlike passive ones, both emits and receives reflected sound echo. Ultrasonic systems are aimed at detecting large objects made of solid materials.

The marine corps use sonars stationed on ships and boats to detect submarines in the water. The reason why the navy doesn't apply radars and sonars for these purposes is in that water reflects both light and radio waves.

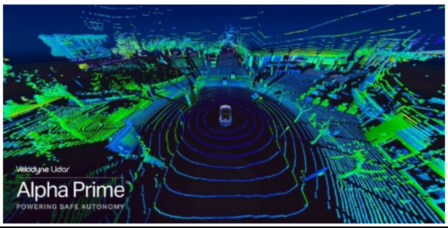
High-level sonars with narrow acoustic-wave beams can detect small boats as well as fish and frogmen in the deep water.

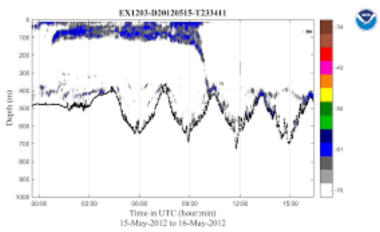
Working.

The ultrasonic system typically consists of the following components:

- **Acoustic pulse generator**: a device that emits soundwaves
- **Transducer**: a component that allows a transmitter to emit acoustic waves in narrow beams.
- **Acoustic pickup**: a receiver for capturing reflected sound waves.
- **Amplifiers**: electronic devices that increase the amplitude of sound waves.
- **Delay timer**: a component that calculates the echo delay. This data allows the ultrasonic software system to determine the distance to detected objects.
- **Indicating display**: A screen that presents processed data in a human-readable format.

LIDAR	*Sonar*
• A LIDAR emits light pulses for ranging. • Visible light waves: 400-700 nm; 430–750 terahertz. • More Accurate. • Less Range • High resolution. • Faster. • Expensive	• Sonar uses sound echo technique and processing. • Ultrasonic waves: 1.5-15 km; 20kHZ-200kHz. • Less accuracy. • More Range. • Low o/p resolution. • Slower. • Cheaper





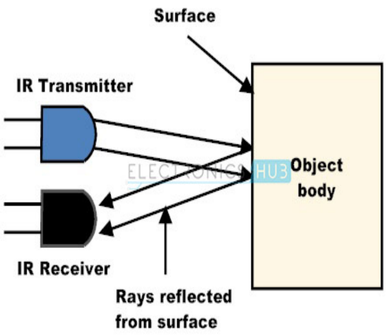
3)LIDAR vs IR

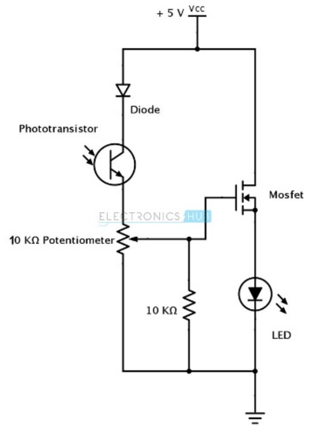
What is IR?

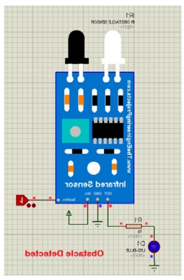
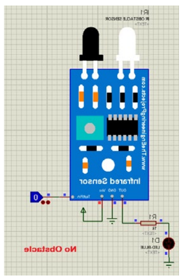
Infra-red receivers are also called as infrared sensors as they detect the radiation from an IR transmitter. IR receivers come in the form of photodiodes and phototransistors. Infrared Photodiodes are different from normal photo diodes as they detect only infrared radiation.

Working.

An IR sensor consists of an IR LED and an IR Photodiode; together they are called as Photo – Coupler or Opto – Coupler. it consists of an IR phototransistor, a diode, a MOSFET, a potentiometer and an LED. When the phototransistor receives any infrared radiation, current flows through it and MOSFET turns on. This in turn lights up the LED which acts as a load. The potentiometer is used to control the sensitivity of the phototransistor.





LIDAR	*IR*
• High Quality • Expensive • Require special software's and data processing. • A LIDAR emits light pulses for ranging. • Visible light waves: 400-700 nm; 430–750 terahertz. • More Accurate. • Less Range • very fast update rate. • High current draw 	• Comparatively low quality. • Cheaper. • Easy interfacing • IR emits, receives light pulses for ranging. • Near infrared region — 700 nm to 1400 nm • Less Accurate. • Less range. • Multiple interface options. • Current consumption a bit high  

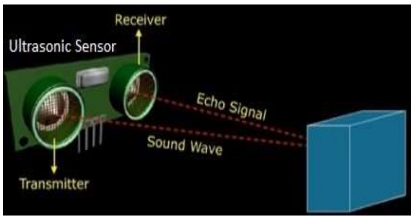
4)LIDAR vs Ultra-Sonic.

What is Ultra-Sonic?

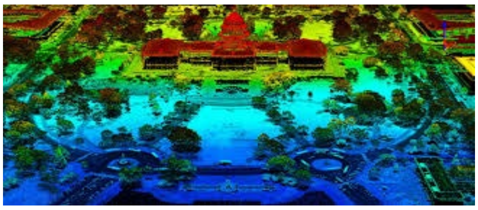
An ultrasonic sensor is an instrument that measures the distance to an object using ultrasonic sound waves. An ultrasonic sensor uses a transducer to send and receive ultrasonic pulses that relay back information about an object's proximity. High-frequency sound waves reflect from boundaries to produce distinct echo patterns.

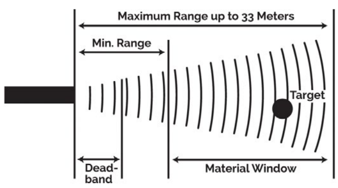
Working.

Ultrasonic sensors work by sending out a sound wave at a frequency above the range of human hearing. The transducer of the sensor acts as a microphone to receive and send the ultrasonic sound. It uses a single transducer to send a pulse and to receive the echo. The sensor determines the distance to a target by measuring time lapses between the sending and receiving of the ultrasonic pulse.

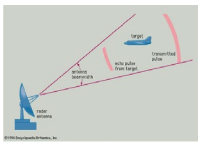
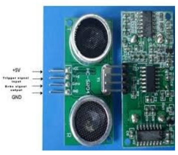
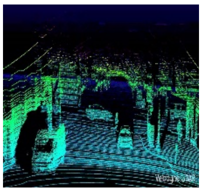
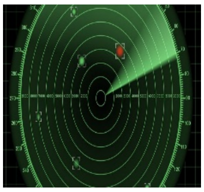
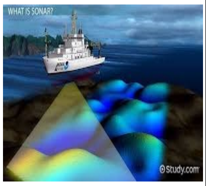
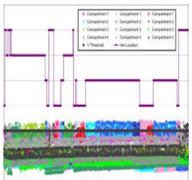
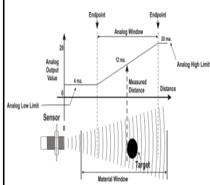


LIDAR	*Ultra-Sonic*
• High quality • Expensive • Require special software's and data processing. • A LIDAR emits light pulses for ranging. • Visible light waves: 400-700 nm; 430–750 terahertz. • More accurate. • More range. • Less distortions due to variation in temperature and other environmental factors.	• Low quality. • Cheaper • It has sensing capability to sense all the material types. • Range 20khz-2mhz • This sensor is not affected due to atmospheric dust, rain, snow etc. • It has higher sensing distance • It is very sensitive to variation in the temperature. • It has more difficulties in reading reflections from soft, curved, thin and small objects.

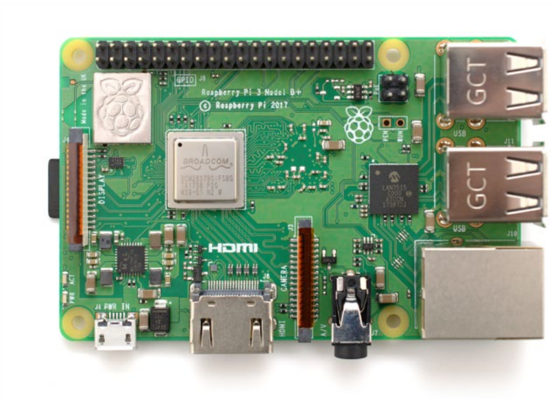




LIDAR vs Radar vs Sonar vs IR vs Ultra-Sonic

Specification	*LIDAR*	*Radar*	*Sonar*	*IR*	*Ultra-Sonic*
Range.	High	Highest	High	Low	Medium
Accuracy.	Highest	High	High	Low	Medium
Resolution.	Highest	High	High	Low	Low
Cost.	Highest	High	High	Low	Medium
Reliability.	Highest	High	High	Medium	High
Spectrum.	Medium	Largest	Large	Large	Large
Weight.	Medium	Highest	High	Lowest	Low
Interfacing.	Highest	High	High	High	High
Power Consumption.	High	Highest	High	Medium	Medium
Operating conditions.	All	Most	Most	Most	Less
Distortions.	Lowest	Low	Low	High	Low
Durability.	High	Highest	High	High	High
Data.	Highest	High	Medium	Low	Medium
Night vision.	Yes	Yes	Yes	Not always	Yes
Velocity measurement.	High	Highest	High	Low	Low
Density of raw data.	Densest	Dense	Dense	Low	Low
Modules.					
Modules.					
Output Data.					

Component and Equipment's Required.



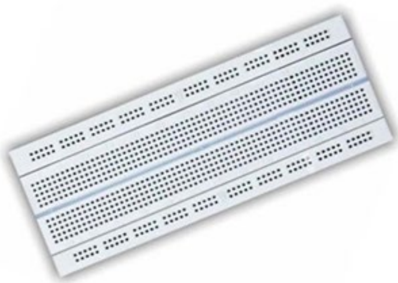
Raspberry Pi Model 3B+

TFMini Plus LIDAR Distance Sensor

Robodo SG 90 Tower Pro Micro Servo Motor

Webcam

Pin Header Strip



Point Breadboard

TFMini Plus LIDAR Distance Sensor

TFmini Plus is a cost-effective -LIDAR. Apart from low-cost, small-size and low-power-consumption, TFmini Plus also has great frame rate, IP65 enclosures and optimizes various compensation algorithms which is ideal for our proto-type project.

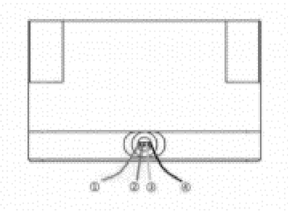
Due to its low weight and simple interface with Raspberry PI 3B+, this LIDAR module was our right choice.

This module is interfaced with Raspberry PI 3B+ using any two available mini UART serial ports, one for receiving data of LIDAR and another for outputting data.

Technical Specifications and Parameters

Parameter		Value
Product parameters	Operating Range	0.1m~12m[1]
	Accuracy	±5cm@(0.1-6m)
		1%@(6m-12m)
	Distance resolution	5mm
	Frame rate	1-1000Hz(adjustble)[2]
	Ambient light immunity	70klux
	Operating temperature	-20℃~60℃
	Enclosure rating	IP65
Optical parameters	Light source	LED
	Central wavelength	850nm
	FOV	3.6°
Electrical parameters	Supply voltage	5V±0.5V
	Average current	≤110mA
	Power consumption	550mW
	Peak current	500mA
	Communication level	LVTTL (3.3V)
Miscellaneous	Material of enclosure	ABS+PC
	Storage temperature	-20℃~75℃
	Weight	11g
	Wire length	30cm

Wiring Guide



Wiring diagram of TFmini Plus

Number	Color	PIN	Function
①	Red	+5V	Power
②	Blue	TXD	Transmit
③	White	RXD	Receive
④	Black	GND	Ground

Commands.

Commands	Downlink frame	Uplink frame	Description
Obtain firmware version	5A 04 01 5F	5A 07 01 01 02 03 SU	Represent V3.2.1
System reset	5A 04 02 60	5A 05 02 00 SU	00-Succeeded 01-Failed
Set update rate	5A 06 03 00 00 SU	5A 06 03 00 00 SU	Set update rate (1~1000Hz)①
Set measure-ment unit	5A 05 05 01 SU	5A 05 05 01 SU	01-cm 06-mm
Set baud rate	5A 08 06 00 00 00 00 SU	5A 08 06 00 00 00 00 SU	Set baud rate②
Enable/Disable output	5A 05 07 00 SU	5A 05 07 00 SU	0-Disable 1-Enable
Restore factory settings	5A 04 10 6E	5A 05 10 00 SU	00-Succeeded 01-Failed
Save settings③	5A 04 11 6F	5A 05 11 00 SU	00-Succeeded 01-Failed

Webcam

A webcam is a camera attached to a computer or in our case a Raspberry PI. Its function is to take the image of the target object and input it to the Raspberry PI for TensorFlow algorithm to process the live video stream and detect objects. We are using a generic webcam with low resolution but works accurately with a detection accuracy of 60%-80%. The webcam is connected to Raspberry PI via an USB com port.

TensorFlow API.

TensorFlow is an end-to-end open source platform for machine learning. It has a comprehensive, flexible ecosystem of tools, libraries and community resources that lets researchers push the state-of-the-art in ML and developers easily build and deploy ML powered applications. TensorFlow is a library developed by the Google Brain Team to accelerate machine learning and deep neural network research. It was built to run on multiple CPUs or GPUs and even mobile operating systems, and it has several wrappers in several languages like Python, C++ or Java.

We are using TensorFlow Lite v1.8 on Raspberry PI,the lite version of TensorFlow provides stability and compromises with speed on low performance devices.

TensorFlow was installed on Rasbpian Buster OS using built-in terminal.

- A new virtual environment was made on terminal to contain all tensor flow packages and python dependencies
- Open CV package is PIP installed to real time detect objects and to interface webcam with our Raspberry PI.
- Several other packages like sudo pip,python 3.7,libatlas,numpy,matlab and virtualenv are installed to process the algorithm's.
- We are using a custom pre trained data set algorithm to detect common objects from the library;Coco SSD dataset which has a reasonable performance-accuracy for our project.
- We can also train our own custom models.
- After these dependencies and packages are installed, we can activate TensorFlow by activating out custom environment for TensorFlow on terminal.

Installation on Raspberry PI terminal.

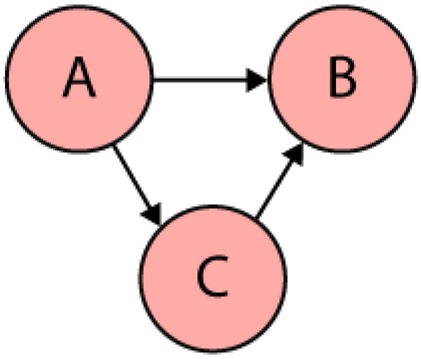
1. git clone https://github.com/TensorFlow/TensorFlow.git
2. cd TensorFlow

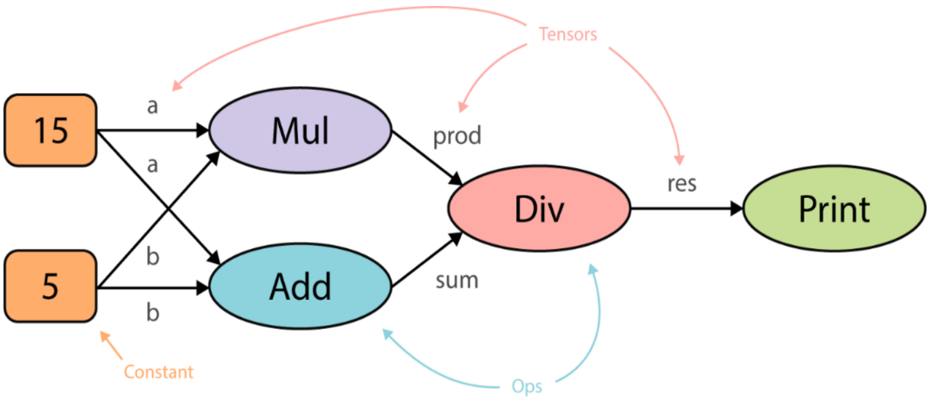
How does TensorFlow API Work?

TensorFlow is a framework composed of two core building blocks — a library for defining computational graphs and a runtime for executing.

Computational Graphs[Tensors]

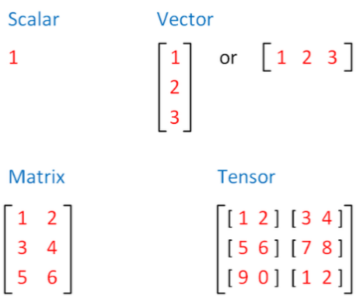
a computational graph is an abstract way of describing computations as a directed graph. A directed graph is a data structure consisting of nodes and edges. It's a set of vertices connected pairwise by directed edges. The edges correspond to data, or multidimensional arrays (so-called Tensors) that flow through the different operations. In other words, edges carry information from one node to another. The output of one operation (one node) becomes the input to another operation and the edge connecting the two nodes carry the value.





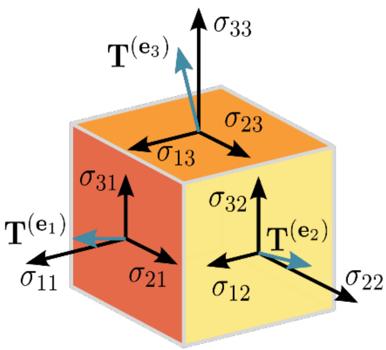
A computational graph in TensorFlow consists of several parts:

- Variables
- Placeholders
- Constants
- Operations
- Graph
- Session



TENSOR

A tensor is a container which can house data in N dimensions, along with its linear operations, though there is nuance in what tensors technically are and what we refer to as tensors in practice.



TensorFlow API Object Detection.

Object detection is the process of finding instances of objects in images. In the case of deep learning, object detection is a subset of object recognition, where the object is not only identified but also located in an image. This allows for multiple objects to be identified and located within the same image.

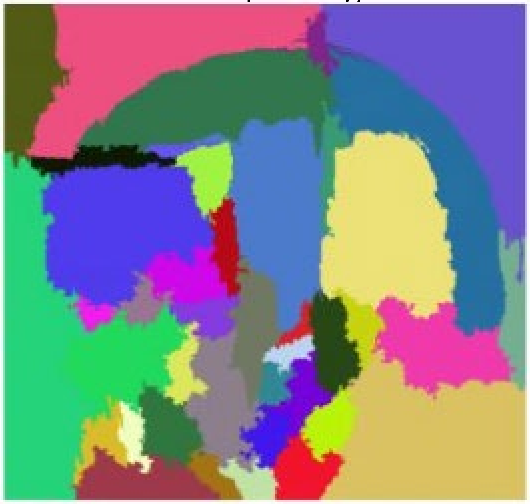
Object Detection uses;

- Convolutional Neural Networks or CNNs
- Instead of working on a massive number of regions, the RCNN algorithm proposes a bunch of boxes in the image and checks if any of these boxes contain any object. RCNN uses selective search
- Edge Detection, Arch/Curve Detection.
- Thermal Imaging.

It first takes an image/Video as input:

Then, it generates initial sub-segmentations so that we have multiple regions from this image:

The technique then combines the similar regions to form a larger region (based on colour similarity, texture similarity, size similarity, and shape compatibility):



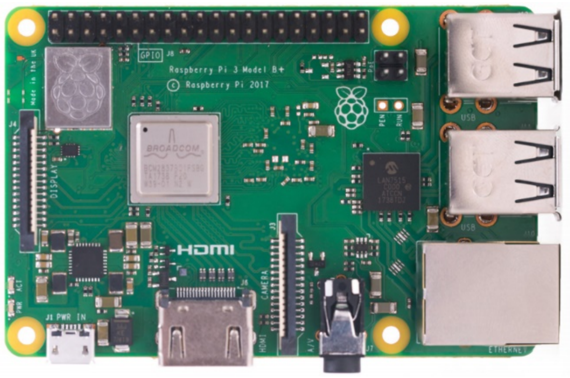
Finally, these regions then produce the final object locations (Region of Interest).

Raspberry PI 3 B+.

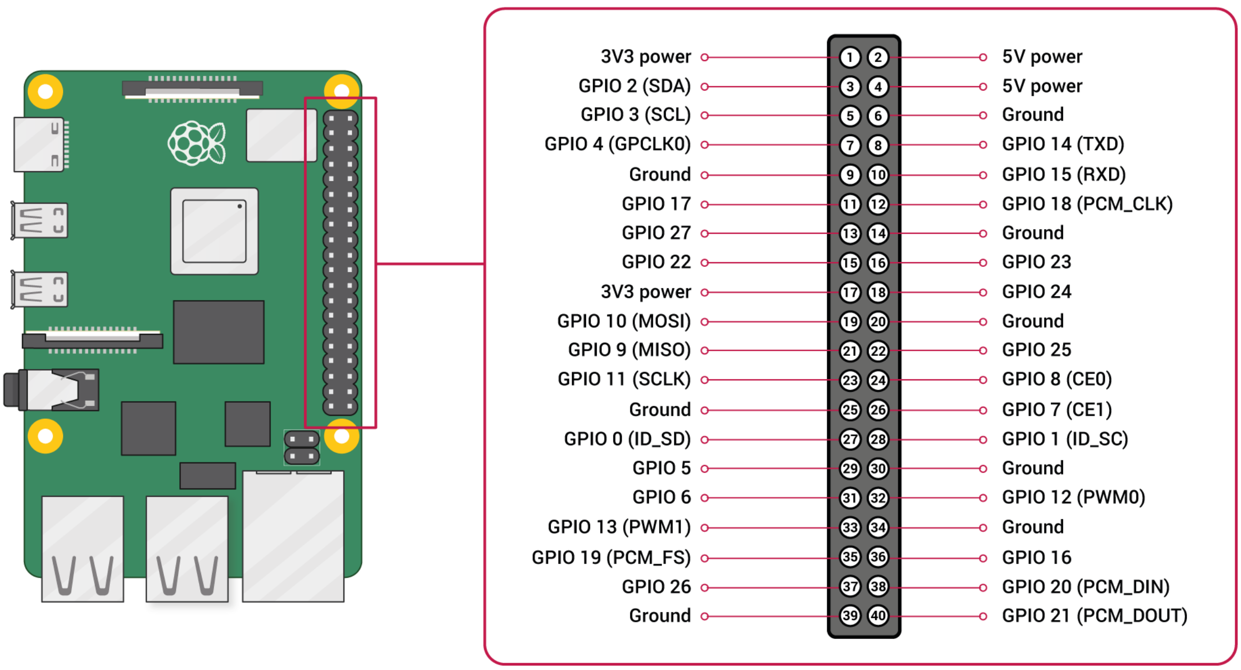
Raspberry Pi is the name of a series of single-board computers that is used for development purposed and so on. The Raspberry Pi is a very cheap computer that runs Linux, but it also provides a set of GPIO (general purpose input/output) pins that allow you to control electronic components for physical computing and explore the Internet of Things (IoT). The Raspberry Pi 3 Model B+ is the latest product in the Raspberry Pi 3 range, boasting a 64-bit quad core processor running at 1.4GHz, dual-band 2.4GHz and 5GHz wireless LAN.

The Raspberry Pi model 3 B+ Specs

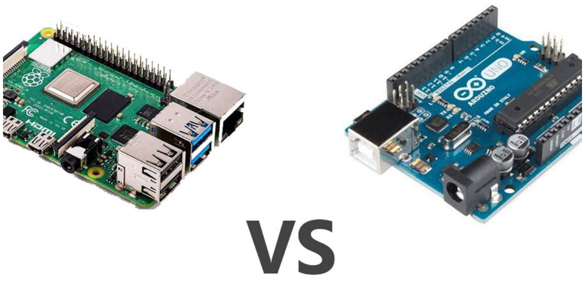
1. **SOC**: Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC
2. **CPU**: 1.4GHz 64-bit quad-core ARM Cortex-A53 CPU
3. **RAM**: 1GB LPDDR2 SDRAM
4. **WIFI**: Dual-band 802.11ac wireless LAN (2.4GHz and 5GHz)
5. **Ethernet**: Gigabit Ethernet over USB 2.0 (max 300 Mbps).
6. **Thermal management**: Yes
7. **Video**: Yes – VideoCore IV 3D. Full-size HDMI
8. **Audio**: Yes
9. **USB** 2.0: 4 ports
10. **GPIO**: 40-pin
11. **Power**: 5V/2.5A DC power input
12. **Operating system support**: Linux and Unix



The Raspberry Pi model 3 B+ GPIO Pin out.



Why we chose Raspberry PI 3 B+ over Development boards like Arduino UNO.

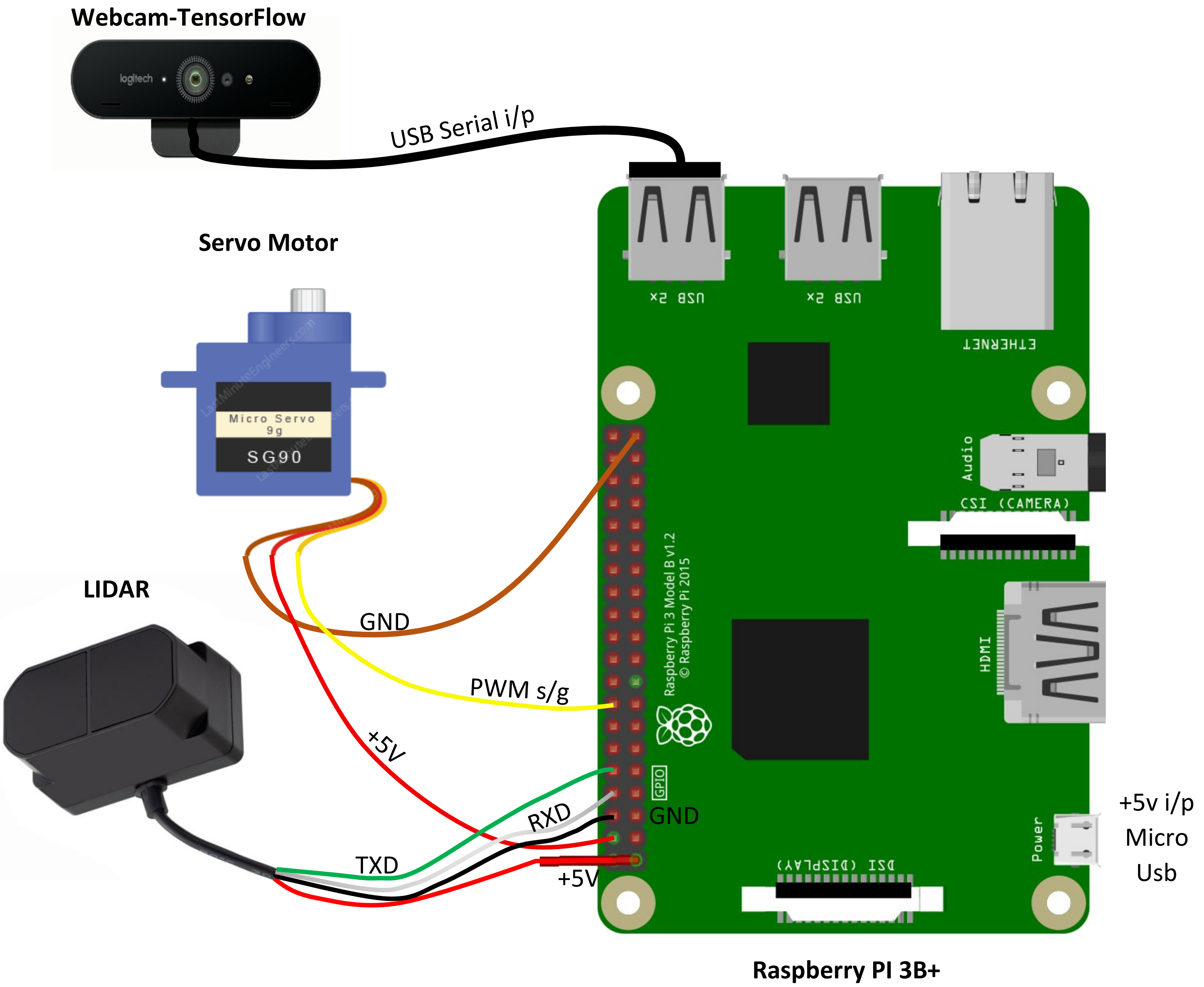


Both boards could be used for development purposes but we chose raspberry PI for our application since;

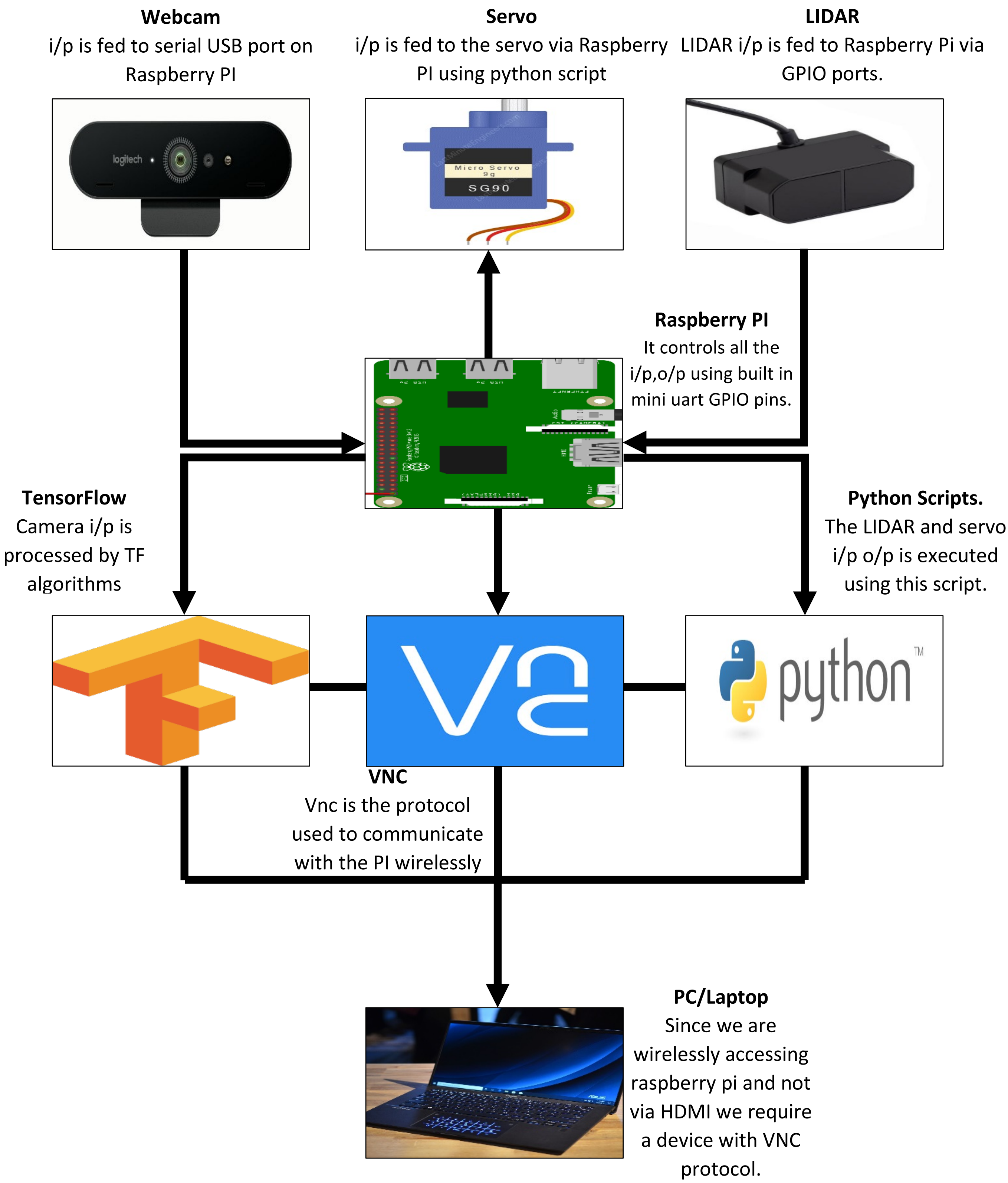
- Raspberry PI is so much more powerful than Arduino hence TensorFlow can run reasonably well on a small device.
- It has raspbian OS which is a Linux distro for Raspberry pi, there for we can run python scripts easily to control our LIDAR and TensorFlow.

- It consumes less power and runs on normal 5v micro USB making it ideal for a self-contained package.
- Raspberry PI has GPIO pins required for LIDAR uart connection we require.
- It has HDMI, or VNC wireless display option hence its ideal.

Project Circuit Diagram



Project Block Diagram.

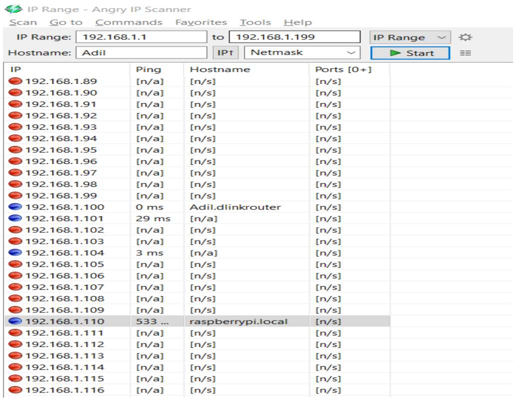


Working

- The python script makes the servos sweep 180 degrees 4 times per second via the Raspberry PI GPIO pin PWM control signal.
- The LIDAR and webcam is mounted on top of the servo which detects the object, its distance and identifies what the object is using tensor flow algorithm processing.
- The LIDAR is collecting data and giving its output to the raspberry pi via its transmit pin and the python script. The LIDAR finally outputs its readings to a separate terminal after executing the python script.
- The camera outputs its data to raspberry pi via the USB serial port which then is processed by TensorFlow algorithms after executing TensorFlow on a terminal window. Finally, a separate window with real time view and object detection appears.
- Both the LIDAR distance readings and object detection window appear on raspberry pi(OS) with real time reading of the object and its detection.
- Raspberry PI is accessed via VNC protocol which allows us to remotely and wirelessly access, control it.

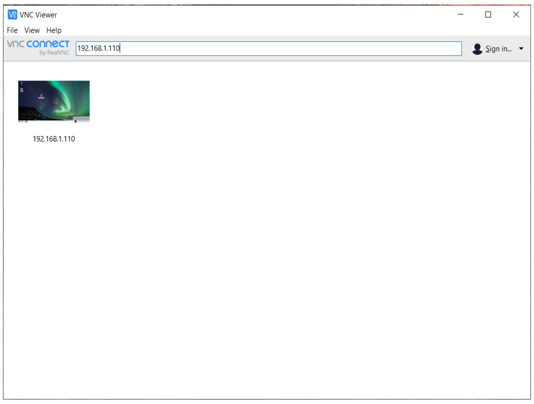
Procedure.

Step 1



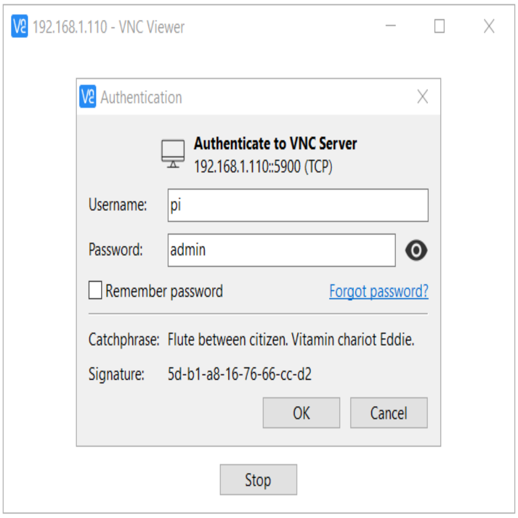
Find the IP of Raspberry PI using CMD or any IP scanners to VNC connect.

Step 2



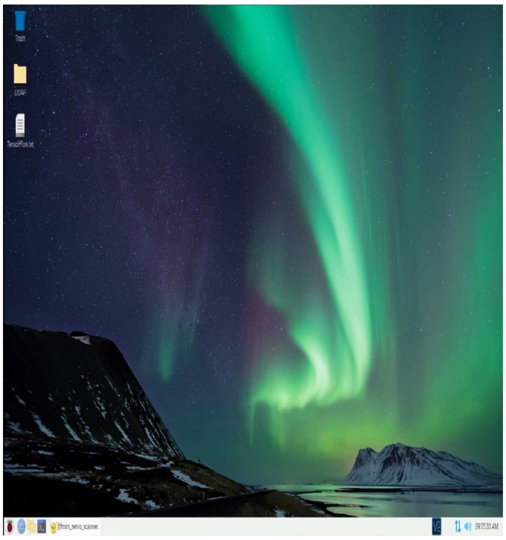
Open VNC server and type in the IP and click connect in which you will be prompted to enter the username and password.

Step 3



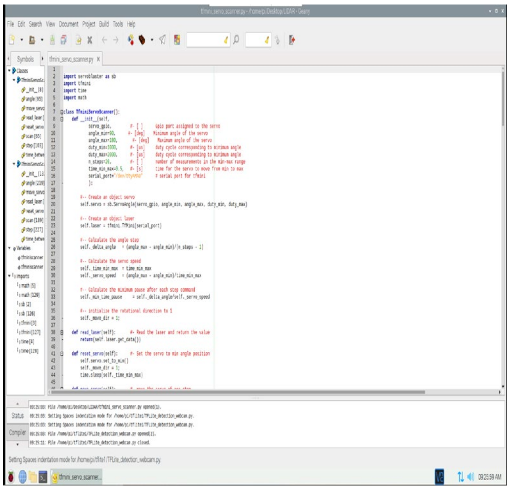
Default Username;pi and password; admin

Step 4



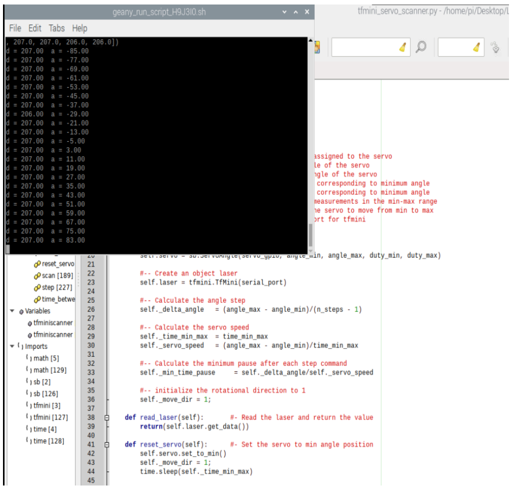
Raspberry PI Desktop.

Step 5



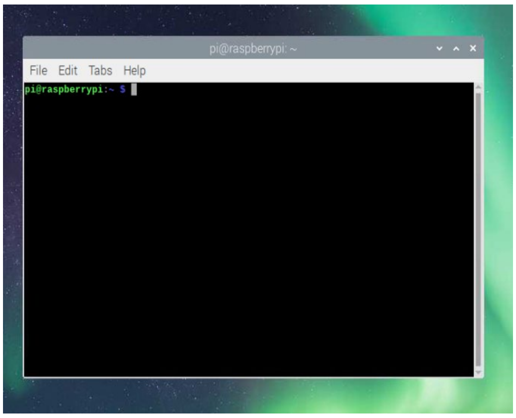
Open the python script for LIDAR and Servo and Run it.

Step 6



A terminal will open with distance readings and angle of the object.

Step 7

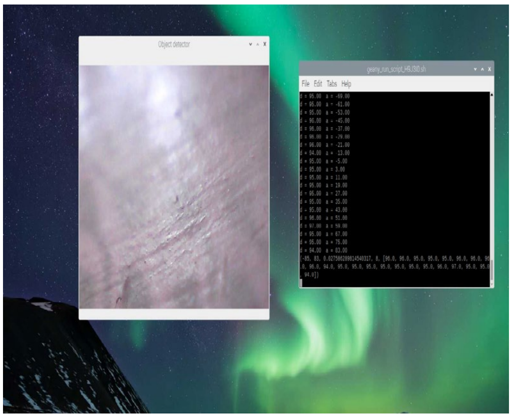


Open another terminal;

1. Type “cd tflite1”to locate TensorFlow environment directory.
2. “source tflite1-env/bin/activate” activates TensorFlow.
3. “python3 TFLite_detection_webcam.py --modeldir=Sample_TFLite_model” runs the python script for object detection.

After sometime a windows with live object detection will appear

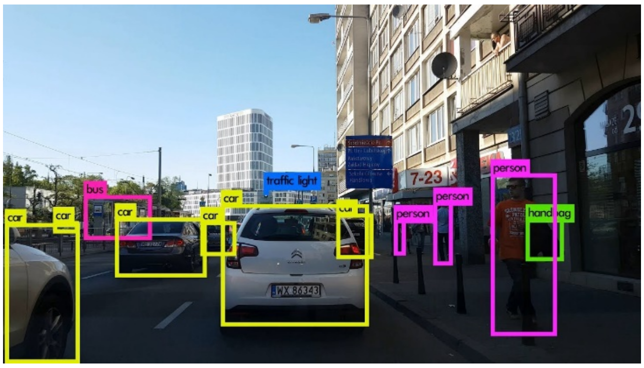
Step 8 o/p

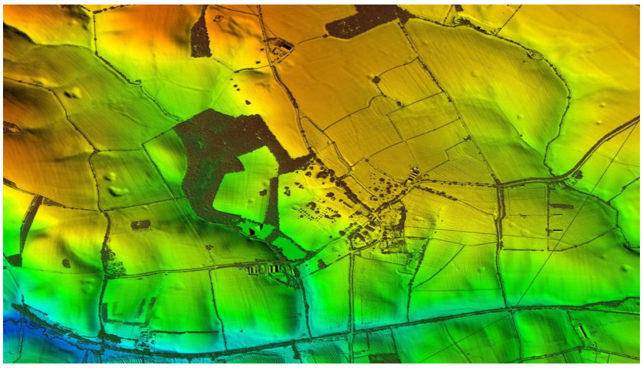


Both the object detection and LIDAR terminals are locked on a window where detection and ranging occurs.

Applications.

- Autonomous Cars; Our project can be installed on cars to make it truly autonomous with 3d mapping and object detection, collision avoidance, pedestrian braking, auto steering, cruise control, emergency braking, accident reduction, traffic stops, maintain lawful speeds etc.
- Autonomous Robots; Robots can map their surroundings and accurately manoeuvre and interact easily.
- Military Applications; Drones, tanks, fighter jets and spy vehicles can easily map inside a building without actually entering there physically, it can also be trained to detect explosives.
- Explosive Detection; Police and military can train the algorithm to detect explosives and accurately find its location.
- Drones; Drones can accurately map the location aerially for civil works and architectural planning's.





Advantages.

- Accurate; Our project has great accuracy up to + or - .1%
- Detection Rate; From 60% to 80%
- Has various applications.
- Isolated single package.
- Customizable algorithms and training.
- Consumes less power than typical systems.
- Future Proof.
- Comparatively cheaper than similar systems

Disadvantages.

- LIDAR's are expensive as of now.
- Complicated Processing algorithms.
- Dependent on different scripts.
- No 3D mapping in our project.
- Tensor flow and LIDAR reading are on separate windows, scripts.

Future Scopes.

- Most cars will be autonomous hence will require advanced machine learning integrated systems like our project.
- Surveillance security systems at airports, public transports etc. need to identify people which makes our system ideal in the future.
- Census counts can be easily taken using this system.
- Police can use this to catch wanted criminals in the future.
- Robots can manoeuvre with little or no human control in the environment.
- Explosives can be detected easily in the future.
- Accident rates can be reduced if our system is implemented on every car.

Our Future Goals.

- Add more sensors and integrate it to our system for more accuracy and fail proof.
- Train TensorFlow to detect many more common objects and create a dataset.
- Integrate our system on a vehicle or a robot.
- Make the circuits smaller and integrated in a smaller package.
- Integrate all the scripts and program into one program.
- Increase detection accuracy by increasing training time.
- Use better LIDAR sensor and high quality camera.

Conclusion.

In the near future where most cars will be electrified and little or no human interaction is required for operating any machines systems like this need to studied and improved upon. India is country where a lot of cars are there and hence can improve the quality of lifestyle in people. Accident less prone and automated cars, machines, vehicles etc. will increase the economy and safeness of people in the country. Truly automating anything is a vast and ambitious dream therefore we need to start implementing such systems in daily life. Ultimately no machinery can overtake the intelligence and nature of any human being hence we need to balance them both and do what's right when implementing such systems. LIDAR and TensorFlow is a complicated system but its interesting, advanced and customisable.

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