Drone Based Surveillance and Tracking System for Poachers and Animals in Forest Areas

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Project Guide: Dr. Hemanth C

MOTIVATION

- Poaching is morally wrong and has ecological consequences.
- Poaching cases in India increased by 151% during lockdown.
- Leverage technology to aid wildlife protection by offering a drone based solution.

OBJECTIVES

- Build a drone based solution for preventing poaching and illegal hunting to preserve wildlife.
- The drone must be have a robust collision avoidance system, and should autonomously travel to the area of interest.
- Detect poachers and endangered animals in real time video stream from onboard camera.
- Send alerts to authorities upon detection of poachers.

LITERATURE SURVEY

Paper title, journal name, year	Main point of the paper	Remarks
Unmanned Aerial Vehicles (UAVs): Collision Avoidance Systems and Approaches, IEEE Access (vol. 8), 2020	This paper provides a survey of collision avoidance techniques used in UAVs, namely optimisation-based, force-field based, sense and avoid, geometry based. It also provides an insight on active and passive sensors for perception of objects.	Computational and economical constraints are balanced with accurate perception so that we have a robust obstacle avoidance system prompted us to use a combination of stereo vision and ultrasonic sensors for perception, and a force-field approach for avoidance.
Autonomous Navigation System for a Delivery Drone, Journal of Control, Automation and Electrical Systems, 2022	In this paper, a DJI Matrice 100 programmable drone which runs ROS for communication between different onboard nodes. Vector field approach is used for defining the desired trajectory. ArUco markers are used for precise landing.	Using GPS coordinates and state information from the FCU’s inbuilt sensors, we took inspiration from their high level control approach for calculating a minimum distance trajectory to travel efficiently to a defined waypoint
ROS/Gazebo-Based Simulation of Quadcopter Aircrafts, 2018 IEEE 4th International Forum on Research and Technology for Society and Industry (RTSI), 2018	This paper discusses the translation of quadrotor flight dynamics realistically inside of a gazebo simulation environment. The ROS ecosystem is described with MAVROS wrapper for supporting communication with SITL.	The approach used for testing the behaviour of an actual drone realistically using simulation was inspired by this paper. We have also used Ardupilot SITL with gazebo plugin for connecting the virtual instances together.

LITERATURE SURVEY

'Comparative Presentation of Real-Time Obstacle Avoidance Algorithms Using Solely Stereo Vision', IARP/EURON International Workshop on Robotics for risky interventions and Environmental Surveillance-Maintenance. Sheffield, January, 2010	The paper talks about three different methods used to perform obstacle avoidance using a stereo camera. Each method works by dividing the view into a grid and performing different operations on the pixels in each grid window.	We have used a similar approach in our project after modifying the existing mechanism to work for a drone that can move in eight directions instead of two.
'Object Detection and Measurement using Stereo Images', Multimedia Communications, Services and Security, June, 2012	The paper talks about object detection in stereo images and calculating the distance, size and the speed of the object in real time using the disparity image obtained.	The method mentioned can be used to detect objects (poachers or animals) in the image for our project but is not suitable to distinguish amongst the two.
'Animal Detection Using Thermal Images and Its Required Observation Conditions', Multidisciplinary Digital Publishing Institute, July 2018	The paper provides algorithm for detecting wild animals using thermal image as input. Detection of non-moving targets were suppressed and only moving targets were extracted.	The shortcoming of this paper is that it doesn’t address the case for non moving animals.

LITERATURE SURVEY

'Forward Collision Detection using a Stereo Vision System', IEEE 4th International Conference on Intelligent Computer Communication and Processing, September, 2008	The paper talks about collision detection used in a car using Stereo Vision System using Drivable Tunnel Model.	Our system does not employ the use of lanes because of which the method mentioned in this paper becomes very difficult to implement.
A wireless sensor network to monitor and protect tigers in the wild, Ecological Indicators, Volume 57, 2015, Pages 447-451, ISSN 1470-160X	A WSN is simulated using QualNet. 2000 XBee-Pro sensor modules are placed to monitor tigers in a 2000 sq km area. Sensors transmit their data to a UAV, which retransmits to the base station. AODV routing protocol is used to search for a possible route to transmit the data only when needed.	We are using a WSN to estimate animal/poacher movement. Upon getting triggered, the coordinates of that particular mote is reported to the base station using an appropriate routing protocol.
Obstacle Avoidance for Quadcopter using Ultrasonic Sensor, Journal of Physics: Conference Series, 2017	In this paper, an obstacle avoidance method for UAVs is proposed using one ultrasonic sensor. The sensor is mounted on a servo motor which swivels 25 degrees in the 2-D plane to scan for obstacles in its angular range. Arduino Uno is interfaced with a pixhawk FCU which generates PWM commands to execute the avoidance move.	In our approach, eight ultrasonic sensors are interfaced with an arduino but are rigidly attached to the quadrotor frame to ensure object detection in throughout the 2-D plane. Raspberry Pi communicates with the FCU, ensuring no error in low-level control.

LITERATURE SURVEY

Control and stability analysis of quadcopter, 2018 International Conference on Computing, Mathematics and Engineering Technologies (iCoMET), 2018	This paper discusses the stability and control aspects of a quadcopter. A comparison of PID and SMC based controllers is shown. Different inputs and their impact on stability is elaborated.	In this project, the Pixhawk 2.4.8 FCU is used, which only allows for PID based control as per the ardupilot firmware. We have the option of tuning the Proportional, Integral, and Derivative constants on a trial and error basis.
'AI for Conservation: Aerial Monitoring to Learn and Plan Against Illegal Actors', International Joint Conference on Artificial Intelligence, July 2018	The paper talks about UAVs used for wildlife conservation in continents like Africa. It uses a program called Air Shepherd for deploying poacher detection prototypes.	This project not only employs image processing for poacher detection, but also uses machine learning to predict the future movements of the poachers. This aspect can be implemented in our project.
'A Study on the Detection of Cattle in UAV Images Using Deep Learning', Multidisciplinary Digital Publishing Institute, December 2019	The paper talks about deep learning algorithm in order to detect cows from the aerial image captured by the drone. The breed of the cow in this study is Canchim breed which is similar to Bos taurus indicus. A total of 900 models were trained using CNN algorithm.	The method used in this paper can be extended to other forest animals. However that would require a large number of image data of each and every animal in the forest.

Hardware and Software used

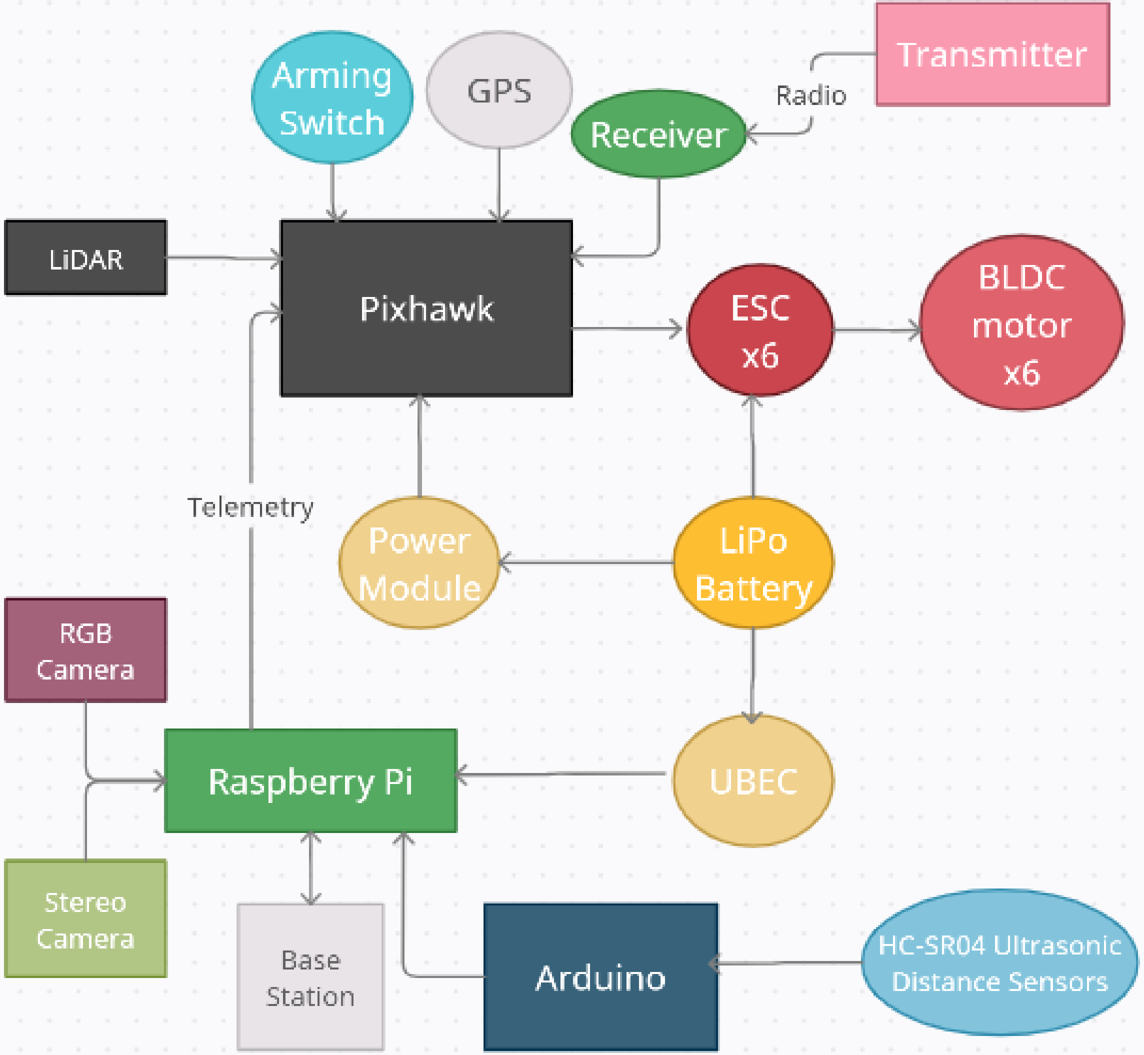
Hardware:

- Raspberry Pi 4B
- Arduino Uno
- HC-SR04 ultrasonic distance sensors
- Hexarotor mechanical components
- Avionics components

Software:

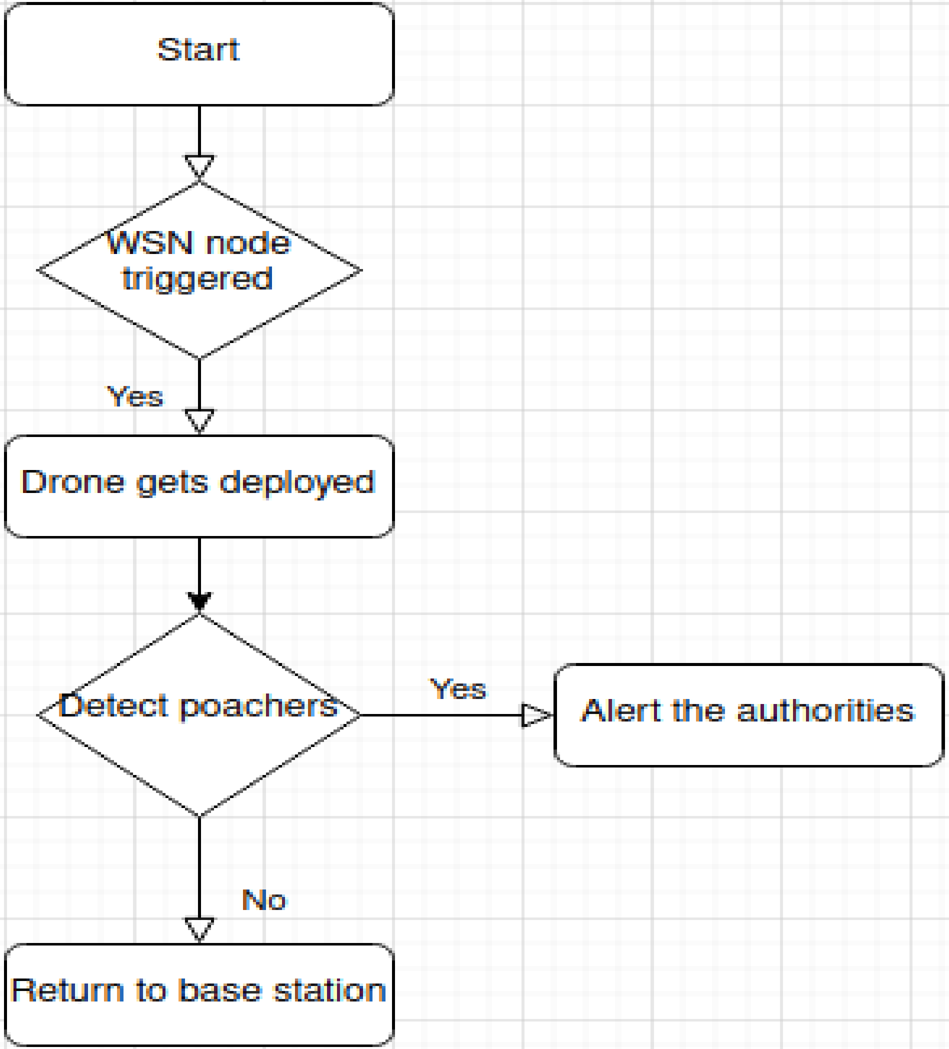
- OpenCV
- ROS
- Ardupilot
- Gazebo
- MATLAB
- Mission Planner GCS
- VirtualBox

Drone Architecture



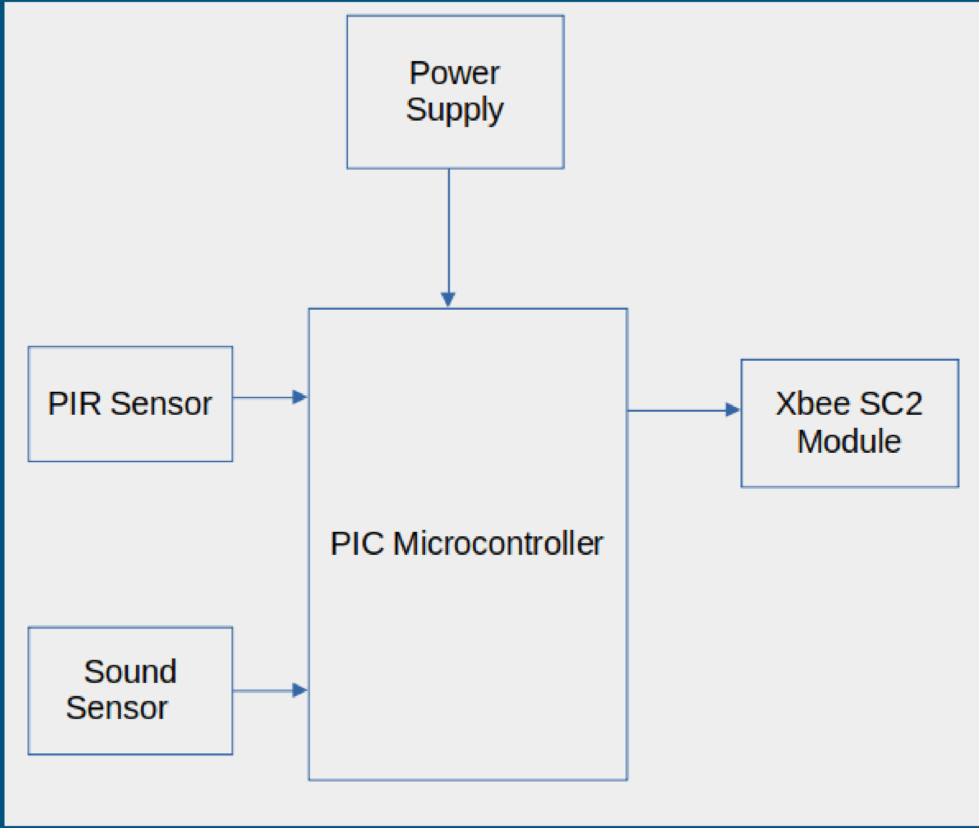
Project Workflow

- Triggered node in the WSN reports its location to the base station.
- Drone travels autonomously with active obstacle avoidance.
- Poacher detection initiated upon arrival.



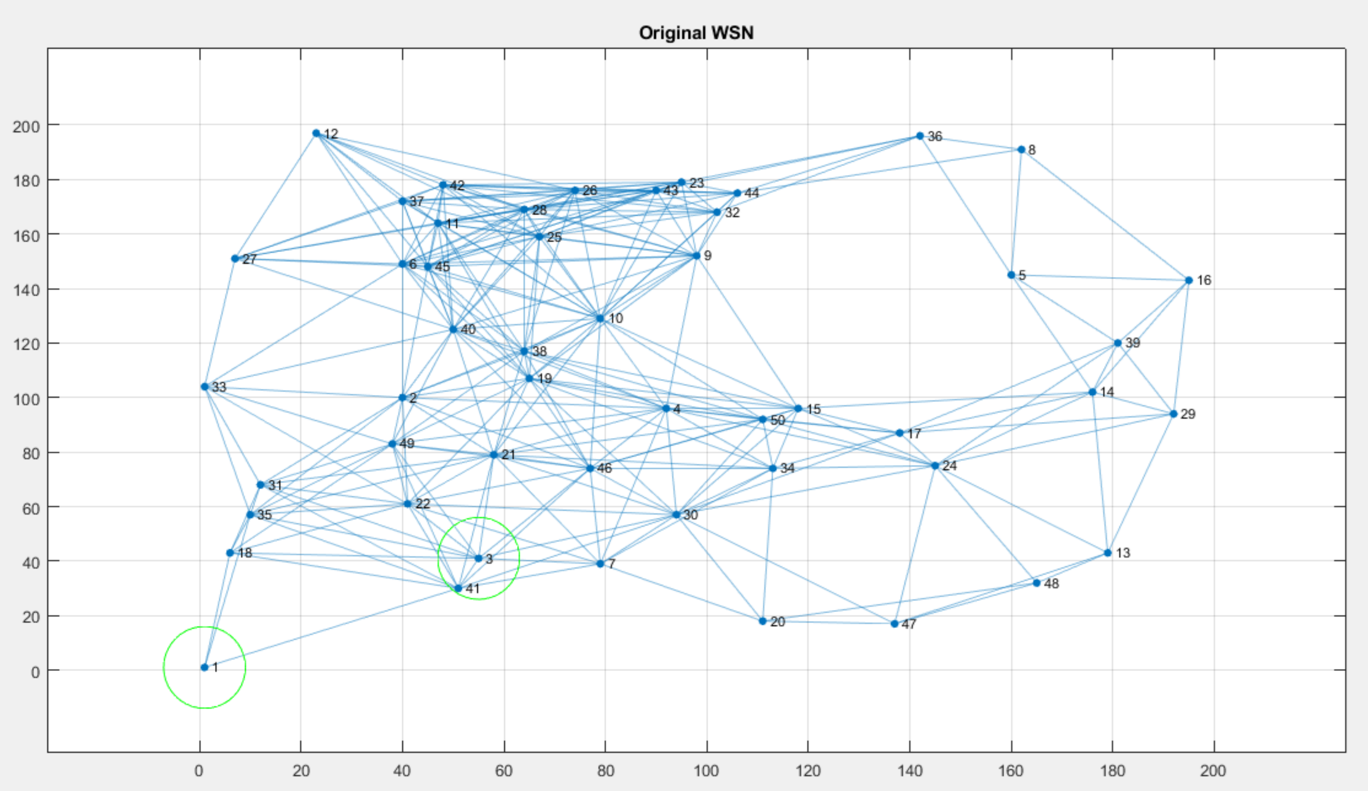
Wireless Sensor Network

- MICROCONTROLLER: PIC Microcontroller
- SENSORS: PIR sensor and Sound Sensor
- COMM PROTOCOL: Zigbee
- ROUTING PROTOCOL: AODV (Ad hoc On-Demand DIstance Vector Routing)

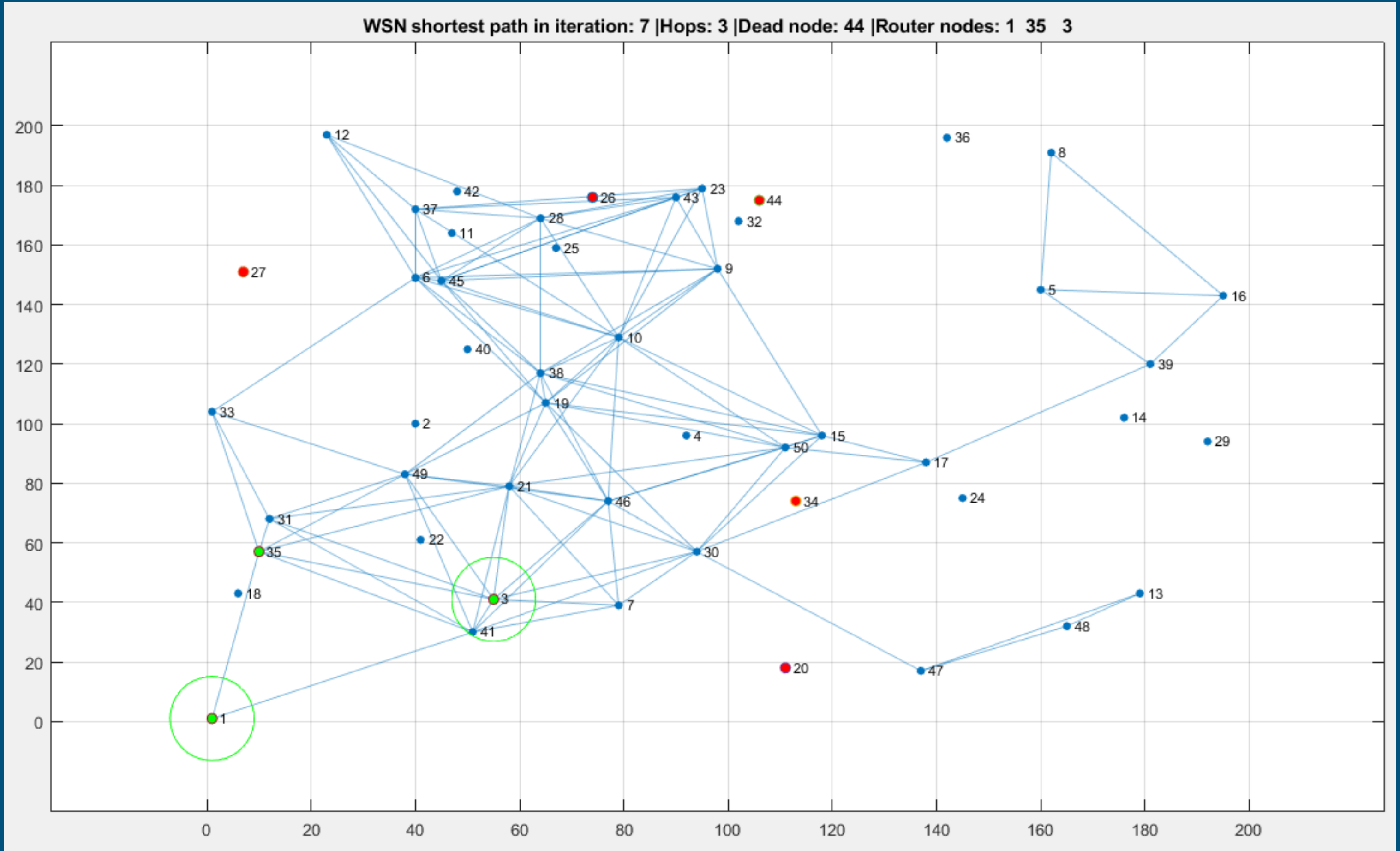


WSN Simulation using MATLAB

- WSN consisting of 50 nodes spread over an area of 40000 sq. meters
- Communication range is 60 meters
- Data routing based on shortest path
- Node 1 set as base station and node 3 acts as triggered node

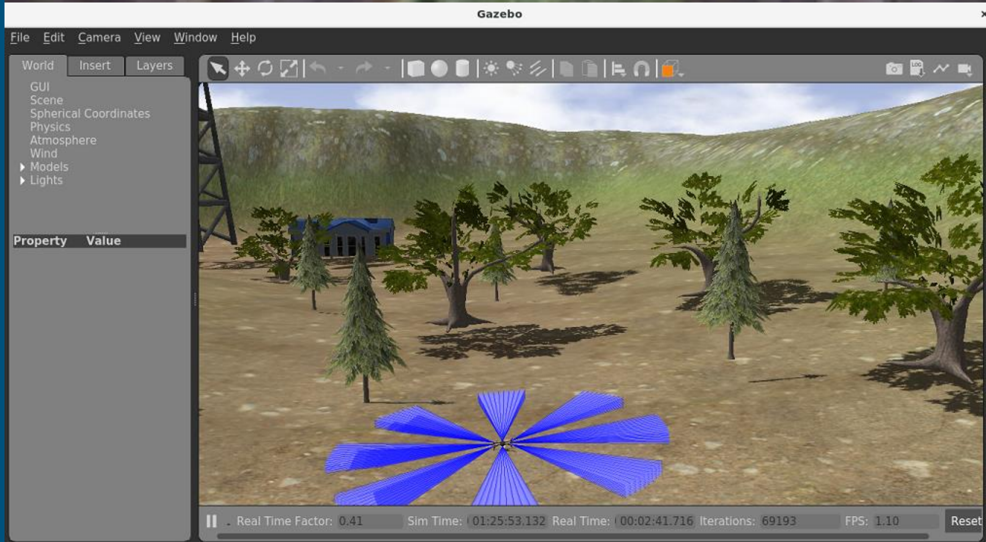


WSN simulation using MATLAB



Gazebo world modelling

- Created a forest like simulation world using Gazebo.
- Linked Ardupilot-SITL with Iris quadcopter.

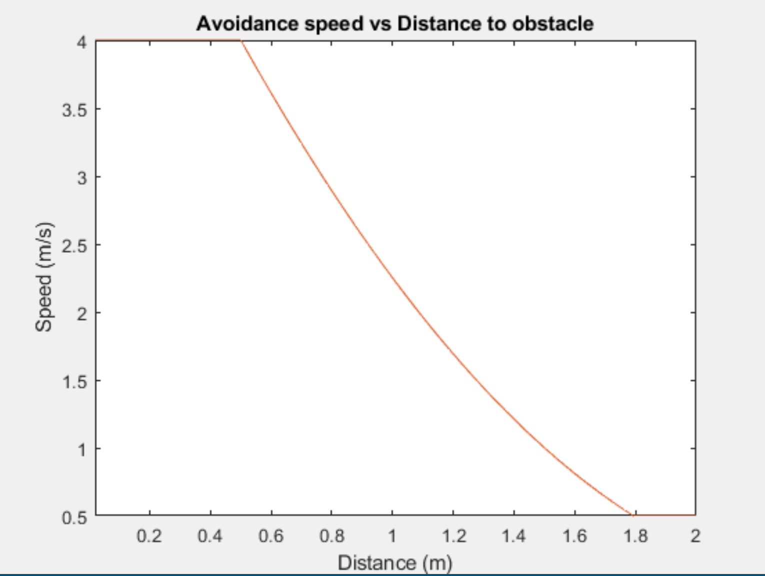


OBSTACLE AVOIDANCE

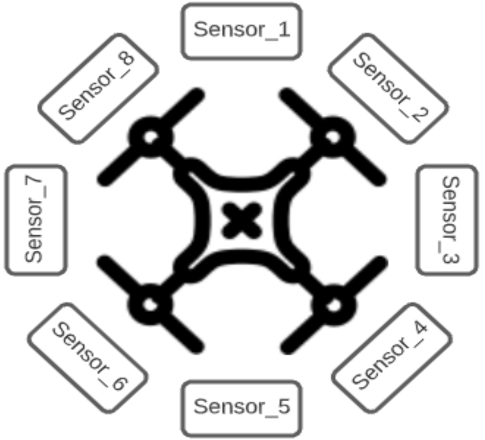
- Need a robust Collision Avoidance System for safely flying through dense forest cover
- We propose a two-fold obstacle avoidance technology, using combined inputs from eight ultrasonic distance sensors and one stereo camera

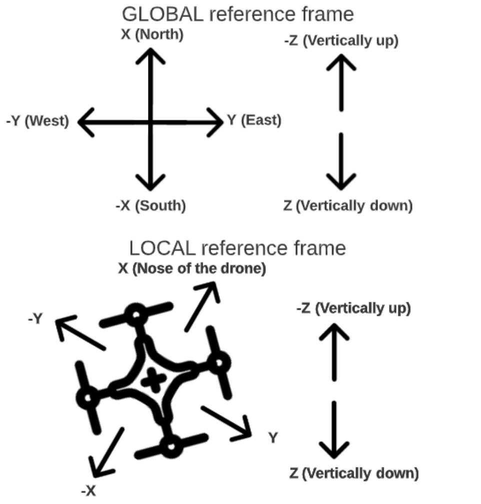
Ultrasonic Distance Sensor based obstacle avoidance

- 8 HC-SR04 sensors arranged at 45° gaps.
- Force-field inspired approach.
- MATLAB for finalising the speed-distance equation.
- Defined in the local reference frame.



V = k1 * (d_obstacle - (d_threshold + k2))^2

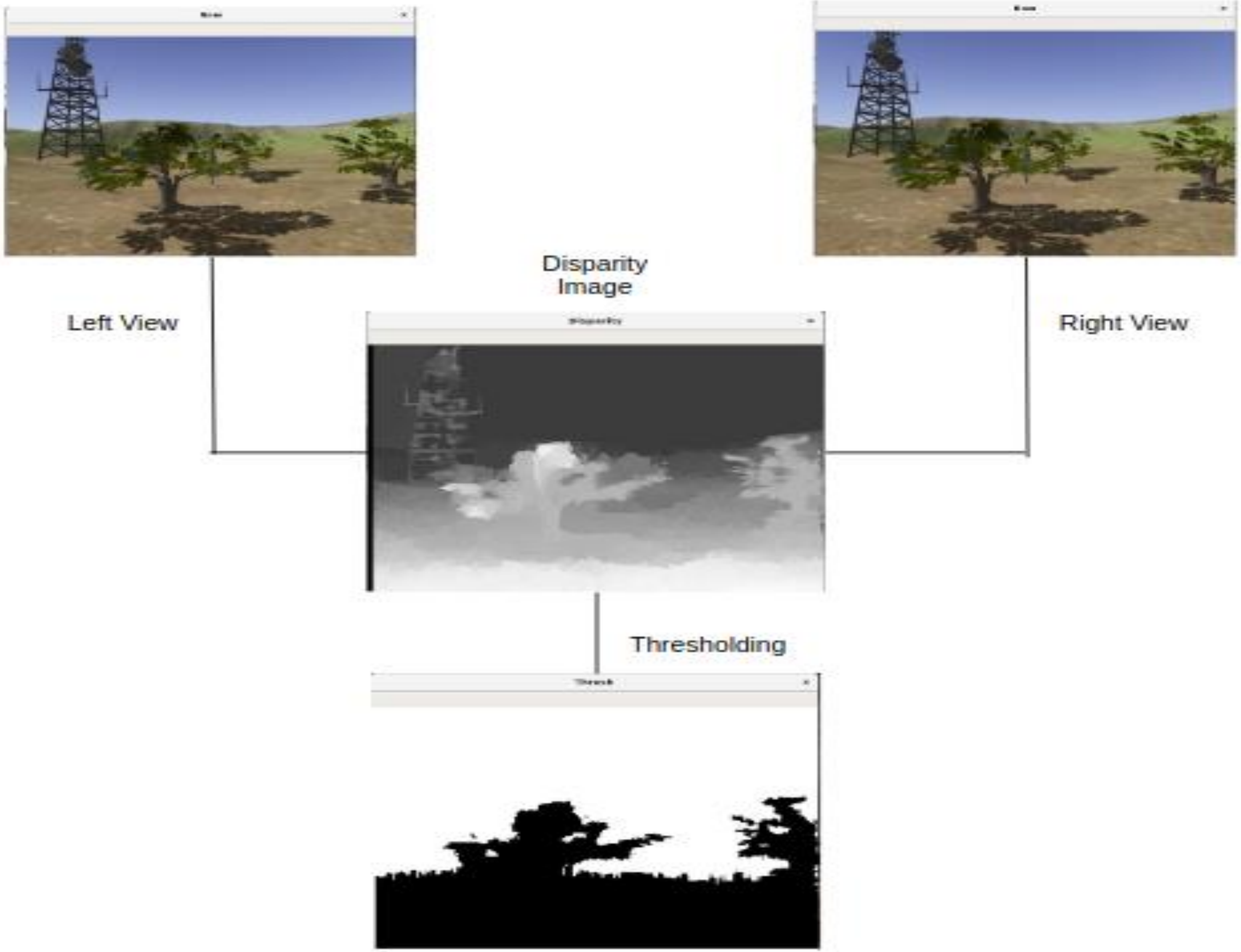




Stereo vision based obstacle avoidance

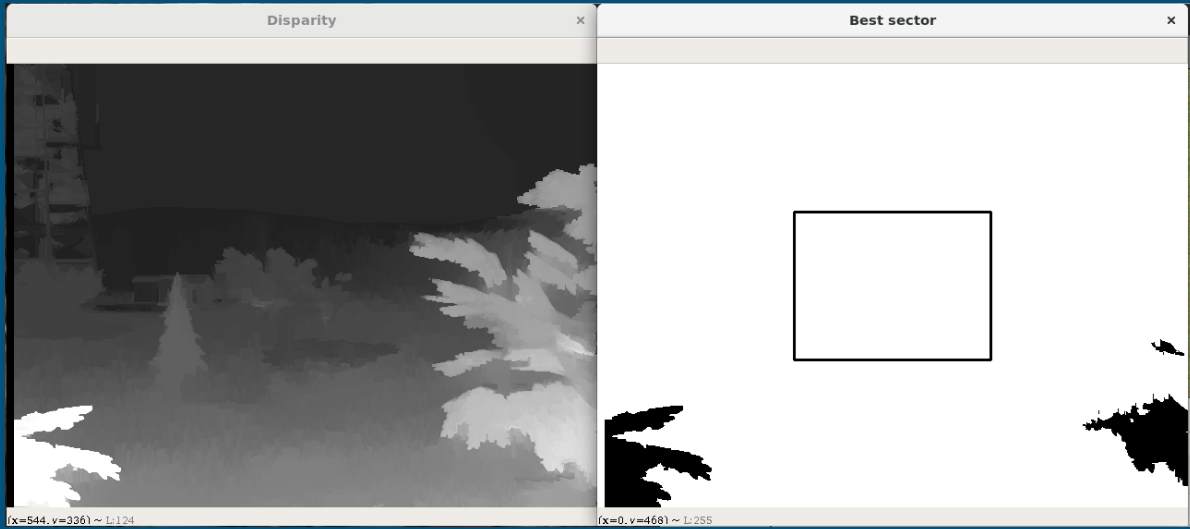
Creating Depth Image

- Disparity map generated using left and right cameras
- Thresholding applied to select objects within a defined distance



Identifying Best Sector

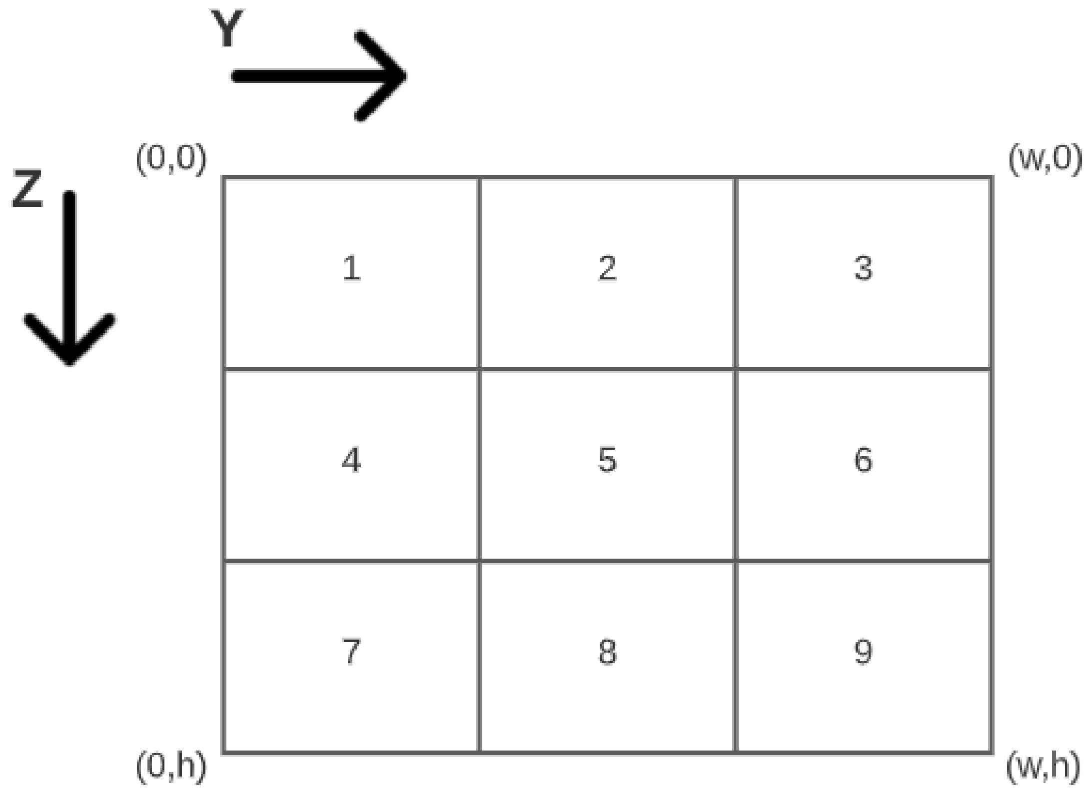
- Thresholded image is divided into a 3x3 grid
- A distance rating is allocated to each sector based on proximity to the center
- A brightness rating is calculated for each sector based on mean brightness
- Score evaluated with the two ratings as weighted metrics
- Sector with highest score is declared as the best sector



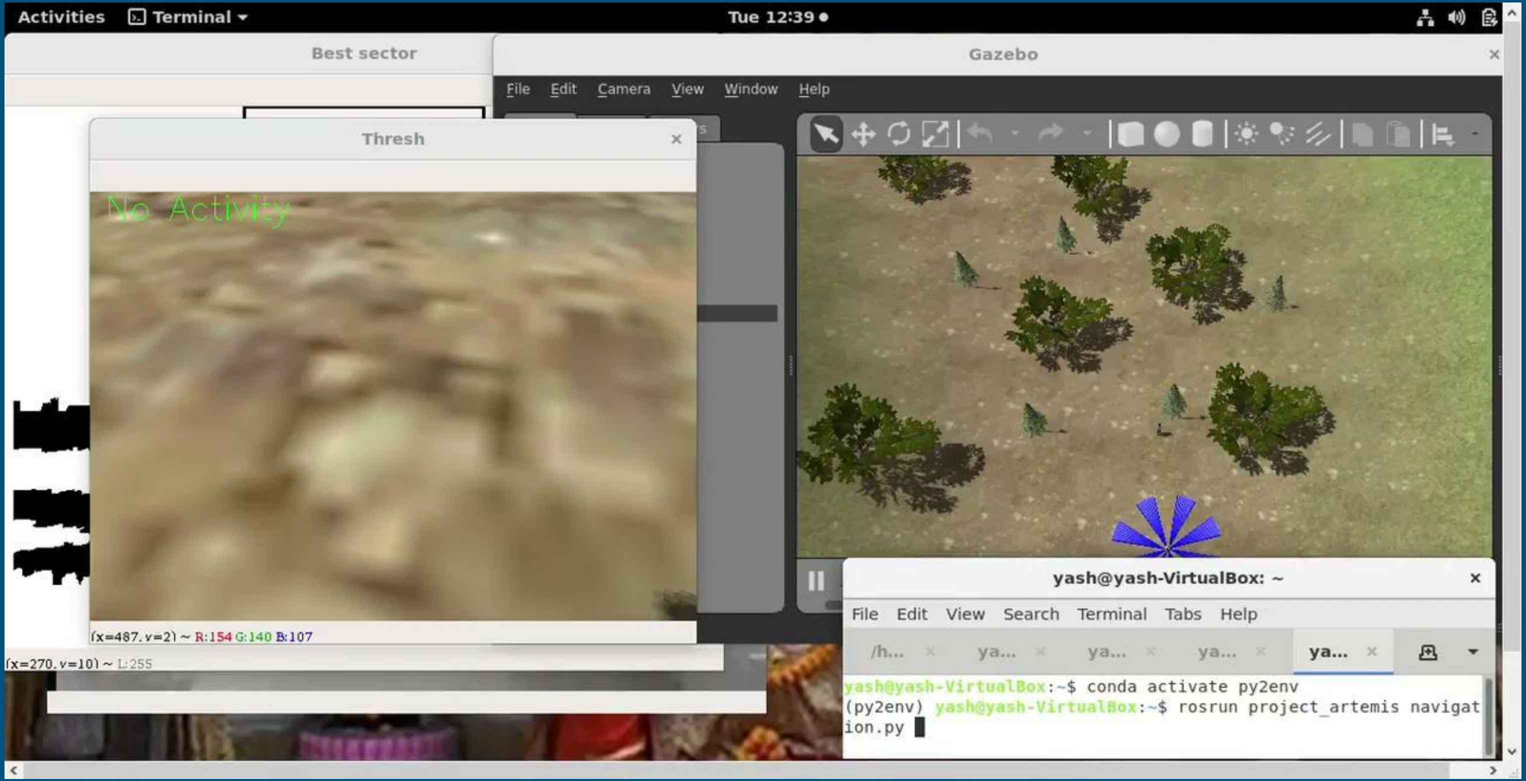
Score = k1*brightness_rating + k2*distance_rating

Moving towards the best sector

- Align the drone’s center with the best sector
- Velocity vector generated in the Y-Z plane in the drone’s local reference frame
- When sector 5 is the best sector, resume navigation



Stereo vision based obstacle avoidance in action

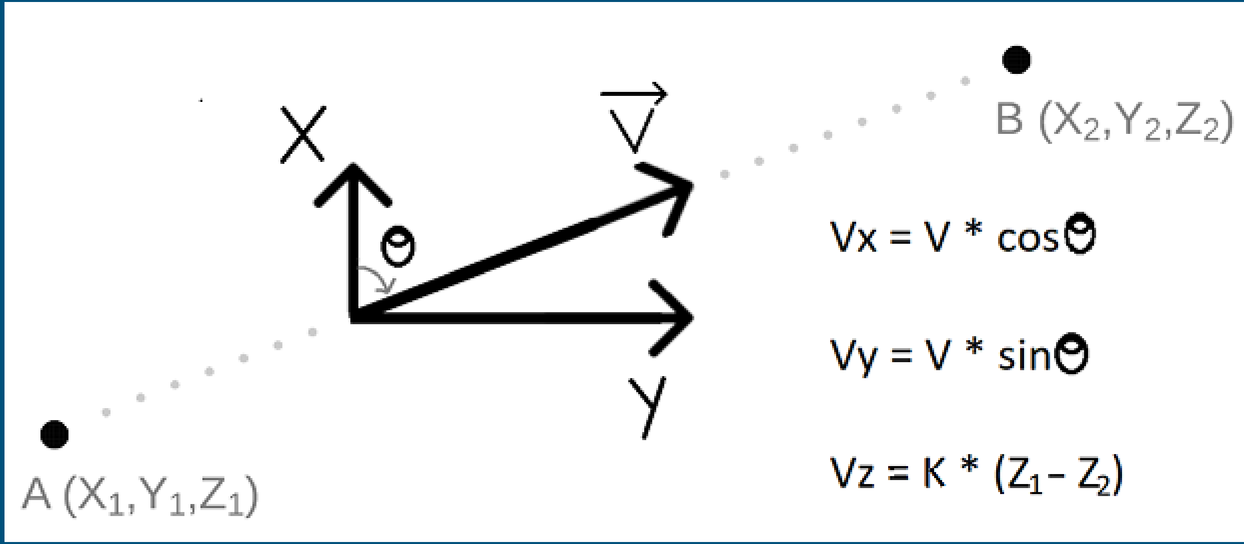


Combined Obstacle Avoidance

- Ultrasonic sensor based avoidance returns avoidance velocity in the X-Y plane
- Stereo vision based avoidance returns avoidance velocity in the Y-Z plane
- Combined avoidance velocity is generated by calculating the Vector Sum
- To ensure low-jerk trajectory, the combined avoidance velocity is weighted

Navigating to Waypoints

- Waypoints are defined in terms of Latitude, Longitude, Altitude
- Heading is calculated using geometry
- Velocity vector is generated in the global reference frame
- If an obstacle is detected, navigation is interrupted

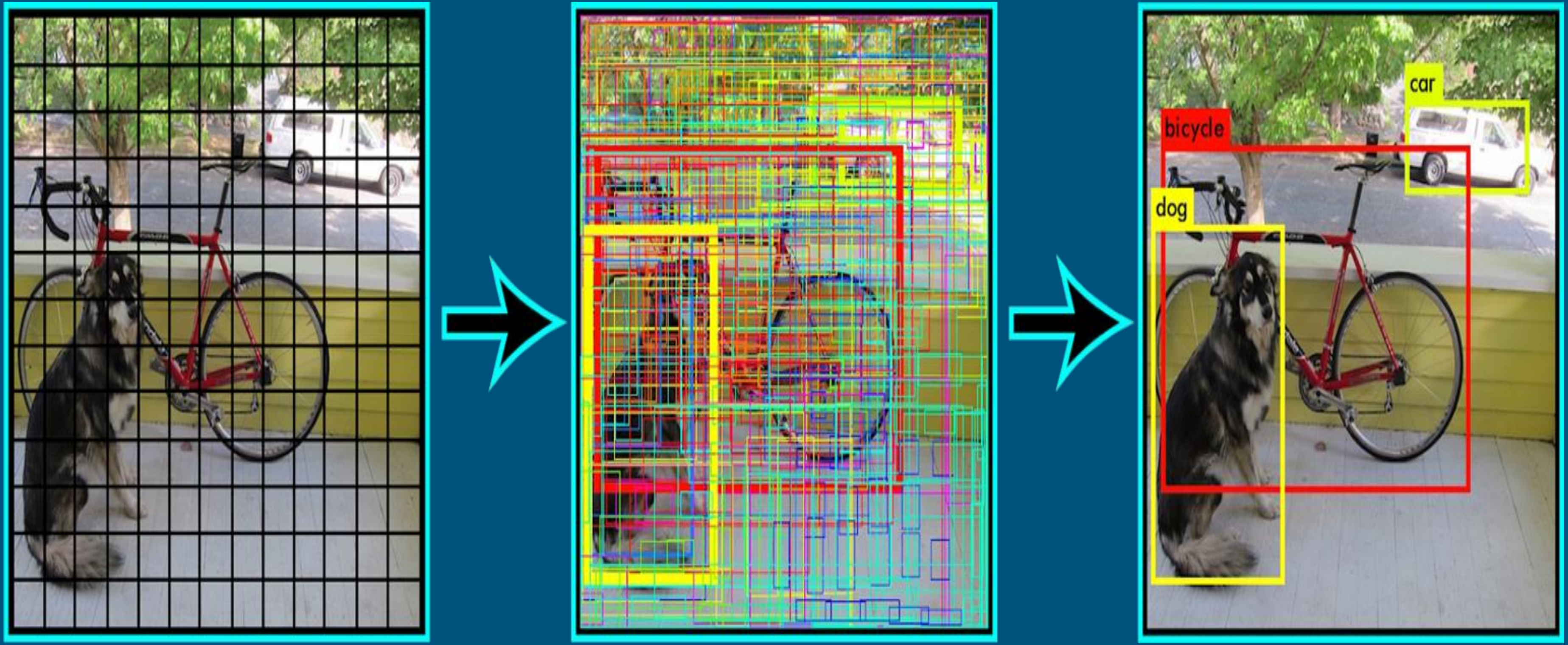


Animal and Poacher detection

YOLO (You Only Look Once)

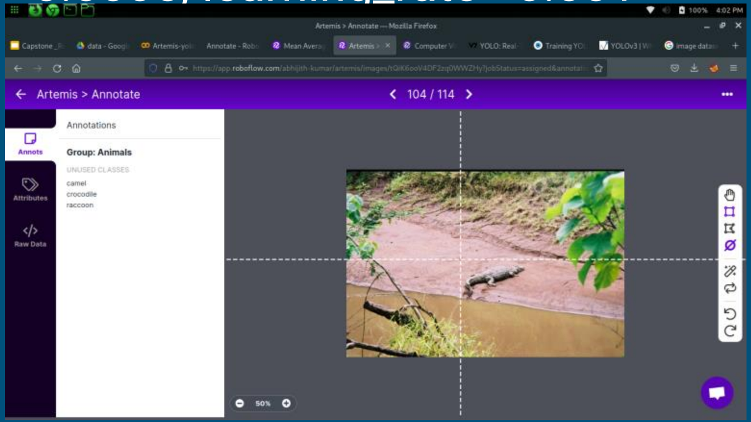
- YOLO works by dividing an image into N-celled grid of dimension SxS.
- Each cell is used to detect the presence of an object along with its bounding box.
- The cells predict certain number of bounding boxes (depending on the version) and tries to predict the confidence score of each bounding box and individual classes.
- The confidence score of bounding box and class prediction are combined to denote if that particular bounding box represents a particular class.
- Non maximal Suppression

YOLO (You Only Look Once)

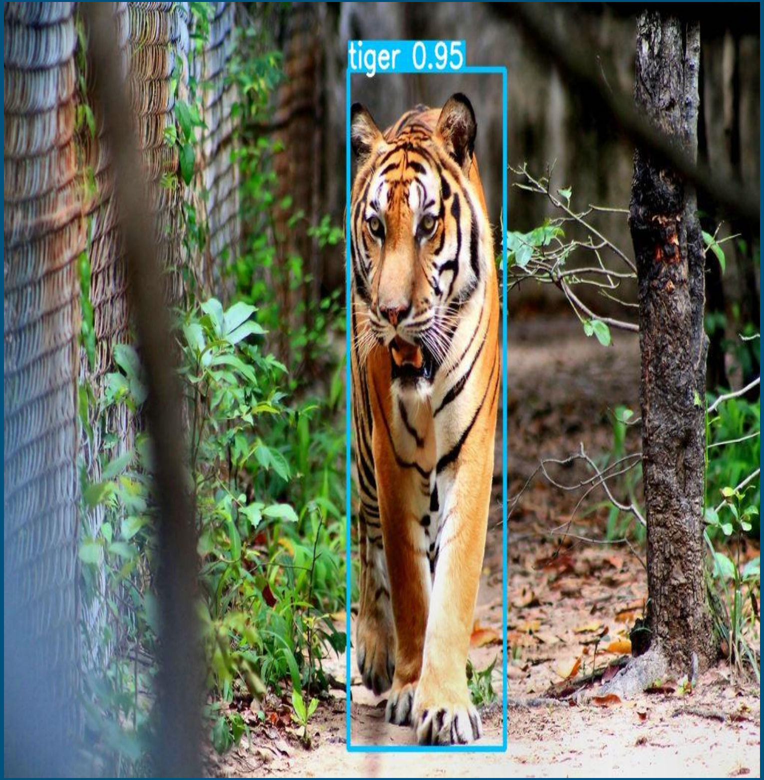


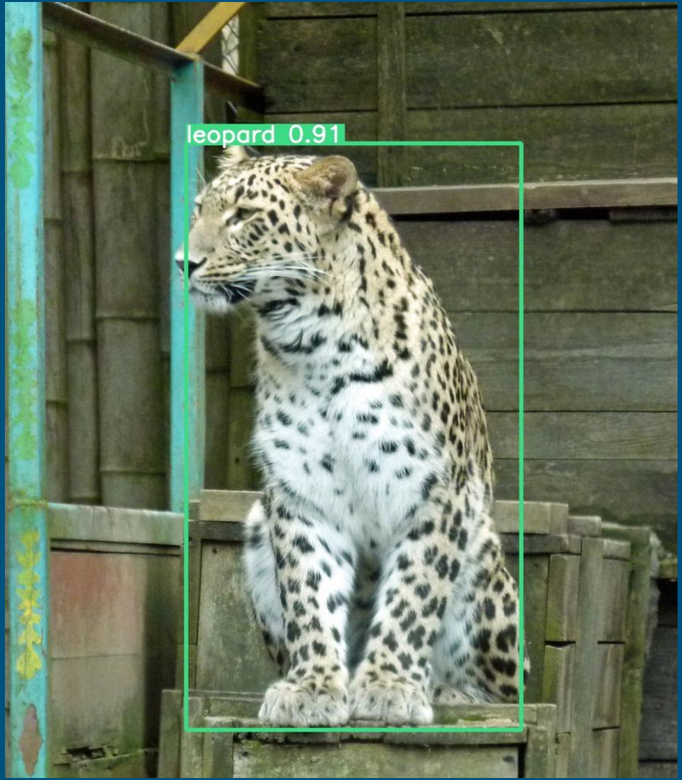
Training custom dataset

- Class: Lion, Tiger, Leopard, Elephant, Monkey, Human, Deer, Bear, Giraffe, Crocodile
- Format of label files: [class] [x] [y] [width] [height]
- Batch size - 16, Epochs - 150
- Momentum - 0.937, weight_decay - 0.0005, learning_rate - 0.001
- Time taken - 1 hour

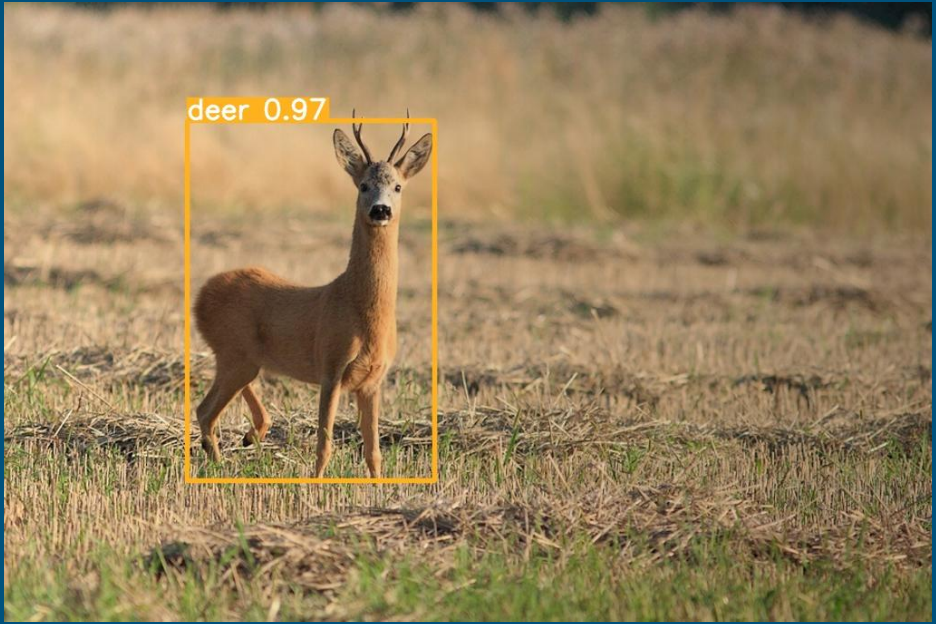


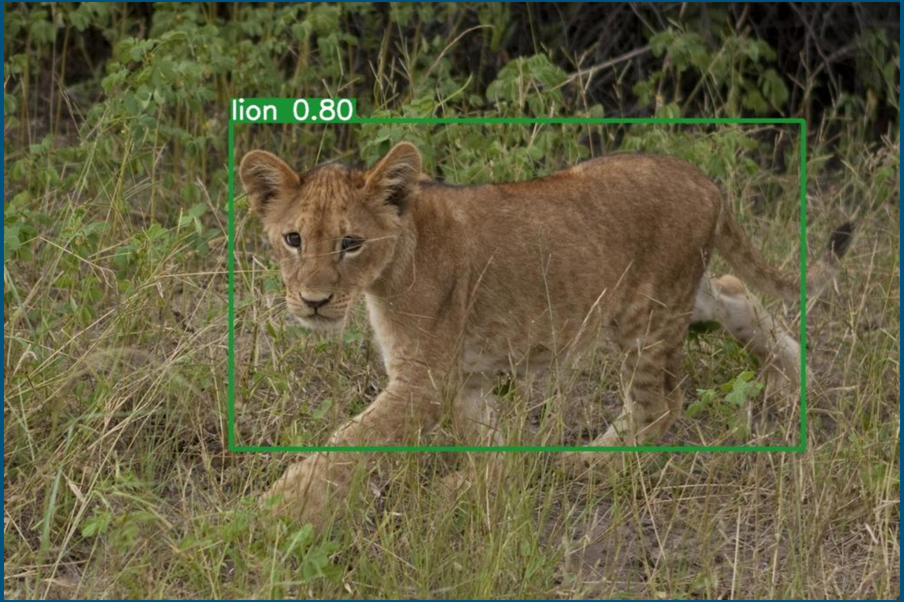
Training custom dataset

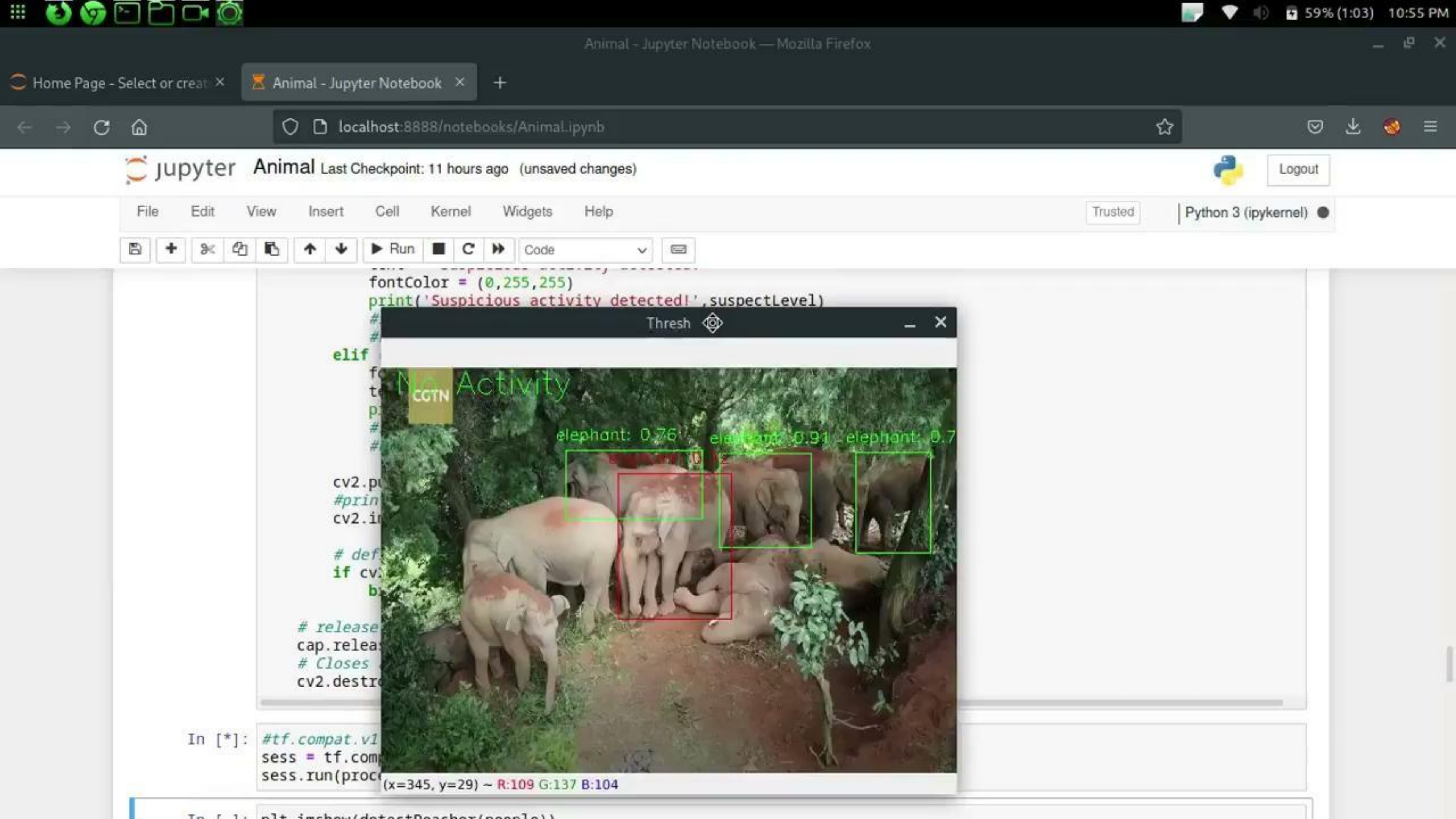




Training custom dataset



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Animal - Jupyter Notebook — Mozilla Firefox
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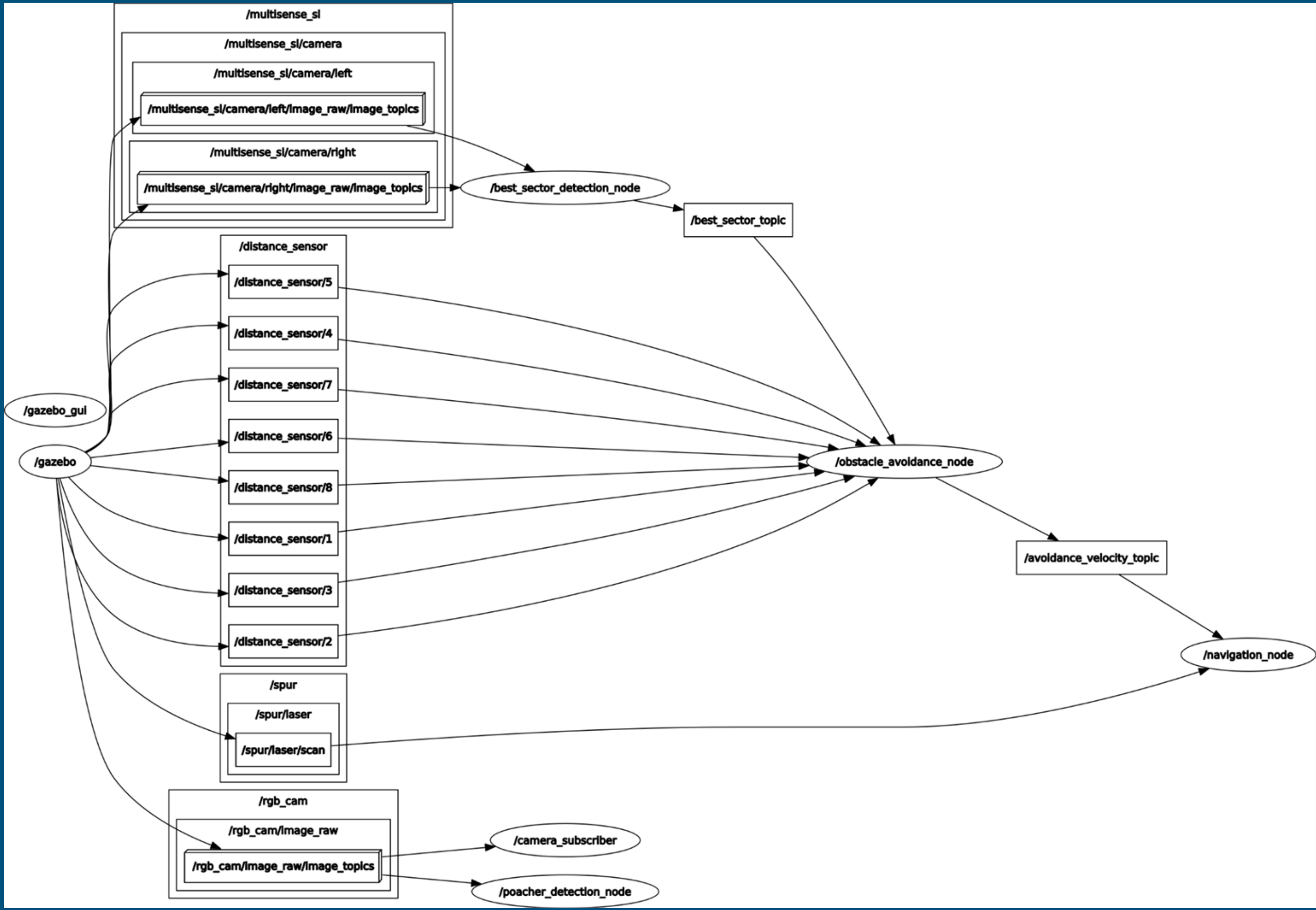
localhost:8888/notebooks/Animal.ipynb
jupyter Animal Last Checkpoint: 11 hours ago (unsaved changes)
Logout
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3 (ipykernel)
Run
Code
fontColor = (0,255,255)
print('Suspicious activity detected!',suspectLevel)
elif
cv2.pu
#prin
cv2.in
def
if cv
release
cap.releas
Closes
cv2.destro
In [*]:
#tf.compat.v1
sess = tf.comp
sess.run(proc
Thresh
No Activity
CGTN
elephant: 0.76
elephant: 0.91
elephant: 0.7
(x=345, y=29) ~ R:109 G:137 B:104

ROS Computation Graph



CODES AND STANDARDS USED

DRONE:

- Communication with base station follows IEEE 802.11n standard at Physical and MAC layer
- Operates at frequency band 2.4 GHz and 5 GHz.
- The channel bandwidth is 40 MHz.
- The maximum data rate is 600 Mbps.
- For video streaming, the protocol used is UDPROS which operates at transport layer (layer 6) of the OSI model.
- UDPROS is just like a regular UDP datagram with a UDPROS header with the fields connection ID , message ID, opcode and block.
- This protocol is implemented in both RFC 768 and RFC 1122, according to which, UDP is an unreliable, connectionless protocol making it useful for streaming video as it doesn’t perform 3-way handshake and is fast and lightweight.

CODES AND STANDARDS USED

WSN:

- For Wireless Communication, Zigbee Protocol is used.
- Operates in the Application Layer of the OSI model.
- Zigbee follows the IEEE 802.15.4 standard at Physical and MAC layer.
- Operates at a frequency of 2.4 GHz with 16 channels.
- It uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA).
- It uses 128-bit AES encryption for secure data connections.

Constraints, alternatives and tradeoffs

- **Constraint** : Lack of aerial images of animals.

  Alternative : Training was done on images of animals irrespective of whether it is an aerial shot or not.

  Trade off : The presence of non aerial images of animals in the dataset makes the YOLO algorithm less effective in detecting animals from the sky.

- **Constraint** : Lack of images of poachers for training.

  Alternative : Training was done on images of humans.

  Trade off : A false alarm can be raised if the drone detects a forest ranger who accidentally trips in one of the sensor nodes

COST ANALYSIS (DRONE)

COMPONENT	COST
Raspberry Pi 4B	₹ 6989
HC-SR04 Ultrasonic sensors	₹ 450
Ublox NEO M8N GPS Module	₹ 1849
Pixhawk 2.4.8 and accessories	₹ 5685
F550 hexarotor frame	₹ 2199
Arduino Uno Rev3	₹ 550
SiK Radio Telemetry 433 MHz	₹ 2163
Orange 3S 2200mAh LiPo battery	₹ 1549
Pixhawk power module	₹ 669

COST ANALYSIS (DRONE)

COMPONENT	COST
GPS stand	₹ 214
10" x 4.5" propellers	₹ 240
Propeller guard	₹ 390
FS-i6 Receiver	₹ 1490
Breadboard mini	₹ 26
Wires, adhesives etc.	₹ 100
UBEC - 5V/3A	₹ 189
SimonK 30A ESC	₹ 2700
DJI 2212 920Kv BLDC motor	₹ 4715
TOTAL	**₹ 32167**

COST ANALYSIS (FOR PROPOSED WSN NODE)

COMPONENT	COST
PIC16F877A	₹ 275
Xbee s2c module	₹ 2699
PIR motion detector module	₹ 71
Xcluma Sound Sensor Module	₹ 199
9V battery	₹ 109
TOTAL	₹ 3353

Approximate cost to set up WSN = ₹ 3353 x n where n is the number of nodes.

Drone Based Surveillance and Tracking System for Poachers and Animals in Forest Areas

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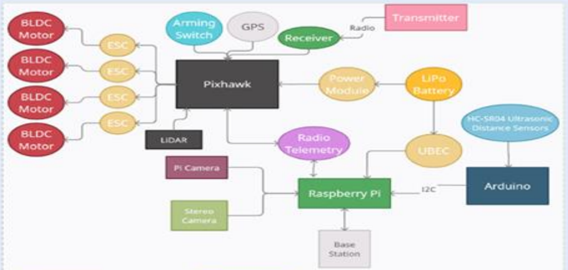
ABSTRACT

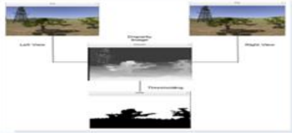
Poaching is morally wrong and has ecological consequences. Recent times have witnessed a large number of horrific poaching cases happening in India. Asiatic Lion, Bengal Tiger, Kashmir Red Stag, Blackbuck etc. are the names of few species in India which have already been driven to endangerment. This paper proposes a drone-based solution to help forest authorities in preventing poaching activity in forest areas. A wireless sensor network in which each node consists of a PIC microcontroller, sound sensor and PIR sensor is set up in wildlife hotspots for detecting intruders. Upon detection, the drone is deployed to the location of the node which is triggered and it travels autonomously whilst avoiding obstacles in the dense forest cover by the virtue of a robust two-fold collision avoidance system. The drone performs poacher and animal detection using a custom-trained YOLO model and if poachers are detected, an alert is raised to the authorities. The Gazebo simulator with ROS is used to validate the navigation, collision avoidance and poacher detection in forest landscape. Collision-free navigation is also demonstrated on a hexacopter which uses a Raspberry Pi 4B as the onboard companion PC for autonomous flight.

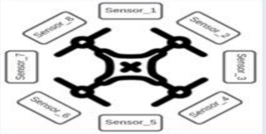
OBJECTIVE & SCOPE

We are building a drone-based solution for preventing poaching and illegal hunting to preserve wildlife.. It has a robust collision avoidance system so that the drone can traverse dense forests. Algorithms for collision avoidance, animals and poacher detection., autonomous navigation to predefined GPS coordinates need to be developed. A a wireless sensor network, with each node consisting of sensors to detect the presence of poachers needs to be created.

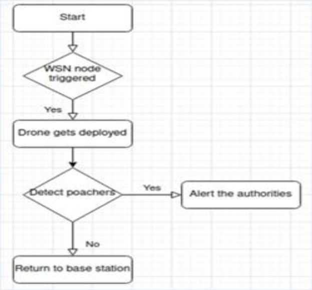
BASIC OPERATION







METHODOLOGY



CONCLUSION

In this project, a drone-based solution to prevent poaching in wildlife hotspots is presented using a drone and a WSN. The limited range of ZigBee protocol (60m) can be overcome using multi-hopping. The drone autonomously travels to the area of interest when one of the nodes gets triggered navigating around obstacles courtesy of a robust two-fold collision avoidance system which uses inputs from ultrasonic sensors and a stereo camera. The drone detects the presence of poachers and animals using the poachers and animal detection algorithm which processes data obtained from the RGB camera using YOLO algorithm. The training phase of the YOLO algorithm involved using a custom dataset consisting of different types of animals which were manually labeled and trained. The drone's navigation and obstacle avoidance algorithms were rigorously tested using simulations run using the gazebo

ALGORITHMS USED

COLLISION AVOIDANCE ALGORITHM: 8 HC-SR04 sensors arranged at 45° gaps which detects obstacles around it using force-field inspired approach. MATLAB was used for finalising the speed-distance equation that forms the basis of this algorithm. The equation came out to be

V = k1 * (d_obstacle - (d_threshold + k2))^2

A Stereo camera is used to generate a depth mapped image. This image is then divided into a 3x3 grid. A distance rating is allocated to each sector based on proximity to the centre. A brightness rating is calculated for each sector based on mean brightness. The score is evaluated with the two ratings as weighted metrics and the one with highest score is declared as the best sector.

Score = k1*brightness_rating + k2*distance_rating

Ultrasonic sensor based avoidance returns avoidance velocity in the X-Y plane. Stereo vision based avoidance returns avoidance velocity in the Y-Z plane. The final velocity vector is generated in the global reference frame. If an obstacle is detected, navigation is interrupted.

POACHER AND ANIMAL DETECTION ALGORITHM: The algorithm used is called You Only Look Once (YOLO). YOLO works by dividing an image into N-celled grid of dimension SxS. Each cell is used to detect the presence of an object along with its bounding box. The cells predict certain number of bounding boxes (depending on the version) and tries to predict the confidence score of each bounding box and individual classes. The confidence score of bounding box and class prediction are combined to denote if that particular bounding box represents a particular class. Non maximal Suppression is used to remove redundant bounding boxes.

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Thank you