Real time Surveillance in Windy/harsh weather conditions with Trajectory Tracking

Quadrotor - Pelican

Project Report/Presentation
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Aim and Objectives

- To get the basic conceptual design phase understanding of the application
    - CONOPS
    - Requirements and Market Survey (esp. For *weather-proof* drones)
    - Design Analyses
- To explore and use the RotorS repository with ROS, Gazebo and RViz to simulate the necessary aspects of this project
- To learn to add sensors and find a way to visualise it
- To visualise wind, using Paraview software
- To implement and execute real time trajectory tracking with camera feed with and without wind
- To tune the control parameters appropriately to achieve stable flight

Contents and Workflow

- Problems of flying under harsh weather
- User Requirements and CONOPS
- Market Survey and Specifications
- Component Identification and Design
- Simulation Details - step by step procedure and explanation (all achieved with wind and without wind)
    - Achieved **drone and environment design** close to the application
    - Achieved **stable flight**
    - Achieved **Trajectory tracking**
    - Achieved live and **real time image/video** data visualisation from pelican's camera in **RViz**
- **Wind Visualisation** - Paraview software

Problems with flying in extreme conditions

- Battery life is severely affected as the drone has to overcome wind, esp. In upstream
- We can expect wind speeds ranging 5 - 8 m/s for this application/design.
- In high altitudes, besides wind, there can be motor failure and blurring of camera lens (This is dangerous when camera is a part of path planning or crucial flight requirements)
  - Low temperatures
  - Condensation due to moisture and fresh snow
  - Heavy Rain (if the drone is waterproof, to model the rain, we can consider the force acting on the drone as similar to wind)
  - Low light (visibility of the surroundings and the drone) - We need high-visibility lights on the body of the craft.
  - Wind during takeoff and landing is more challenging than cruise.
  - Precautions like listed in [3] can be taken to avoid crashing in such conditions

User Requirements

- At least 25 min of flight time
- Max Altitude 1 KM (default can be 200 - 500 m) above the sea level
- It is needed to work in high windy areas (5 - 8 m/s)
- It has to operate within a distance of 1.5KM and come back to the home point.
- The drone is needed for surveillance and real time camera feed.
- For surveillance, specific points or trajectory is given and it has to follow it.

Note: Here, we are considering high altitude region in wind. Temperature and rain can be tackled in a similar way but we need to build a waterproof cover, as in PowerEggX shown in market survey.

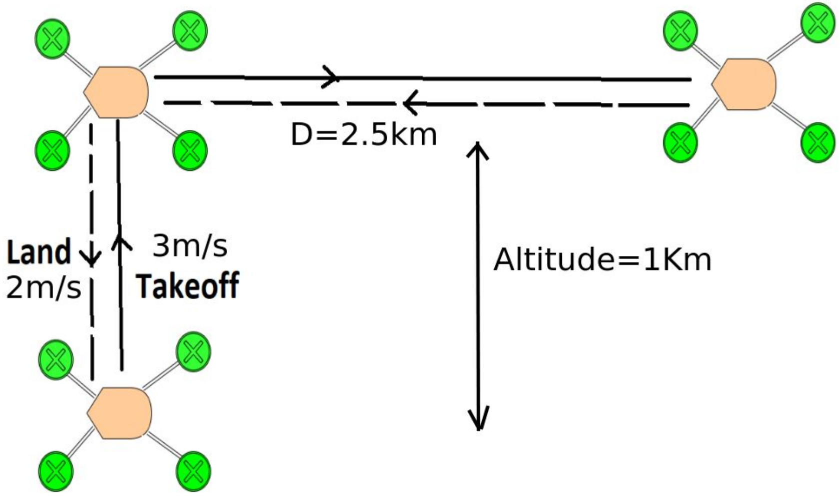
CONOPS

Climb to an altitude of 1km.

Follow the trajectory and capture the images and render them on rviz as real time video feed

Return back to the location of takeoff (as per the specified trajectory)

Descent and land (as specified by the trajectory)



Market Survey - 1

Most of the drones which can be used in rain or snow or heavy wind conditions or high altitudes (with necessary precautions and provided guidelines) are termed *weatherproof* in the market. Some of such drones which are close to satisfying the current requirements are explored and their specifications are mentioned here.

PowerEgg X Specs (water proof)

- Take off weight = 0.89 kg
- Dimensions = 7× 4 × 4 in
- Endurance = 30 min
- Working temperature = 32F - 102F
- Max Ascent Speed = 5 m/s
- Max Descent Speed = 3 m/s
- Max Flight Speed = 18 m/s
- Range = 6 KM
- Max Wind Speed Resistance 8 - 10 m/s (level 5)
- Altitude ~ 5KM

Market Survey - 2

Splash drone 3+ (water proof)

- Drone Weight: 1447g
- Max Ascend Speed: 4m/s
- Max Descent Speed: 3m/s
- Max Flight Speed: 18m/s
- Max Flight Altitude: 1.3 KM
- Max Flying Wind Speed = 8 - 10 m/s
- Endurance = 20 - 23 min
- Payload = 1 KG
- Max take-off weight ~ 3 kG
- Max flight range = 1.6km

Market Survey - 3

DJI Mavic 2 Pro

- Takeoff Weight: 907 g
- Maximum Takeoff Altitude: 6000 m
- Endurance: 30 min (29 in wind)
- Range: 18 KM (at 13.8 m/s)
- Wind speed resistance: 8-10 m/s

Requirement Specifications

Final specifications based on User requirements and market survey are as follows

- Mass (max takeoff weight) = 1.2 kg (including battery and camera)
- Endurance = 30 min
- Wind resistance = 5 - 10 m/s
- Max altitude = 1 KM
- Range = 4 KM (conservative)(to and fro)
- Max Ascend Speed = 3 m/s (initial consideration)
- Max Descent Speed = 2 m/s (initial consideration)
- Max flight/cruise speed = 10 m/s
- Battery considered = 6000mAh (11.4 V)

Sizing and Component Identification

Some sensors are added to the already existing basic sensors in pelican.xacro and pelican_base.xacro file

- Battery, rotors, GPS, Accelerometer, Gyroscope, Magnetometer, Altimeter are default in the autopilot scheme (wt. Accounted in max takeoff wt.)
- Generic Odometry sensor (~15g to estimate the change in the position of the UAV, using other motion sensors) is available in the model and wt accounted.
- Similarly, IMU sensor (7g to measure the external force and angular rates)
- **Camera** - 100 g (payload for video/camera real time data) is **added.**
- Rotors mass is 20*4 = 80g (wt. accounted)
- Body width = 100cm, height = 200cm (wt. accounted)
- LED lights = 5g (wt. accounted)

Endurance and Range calculations

Range that the uav can cover = 2km+0.72km= 2.72km

Endurance = 42 min

Simulation details

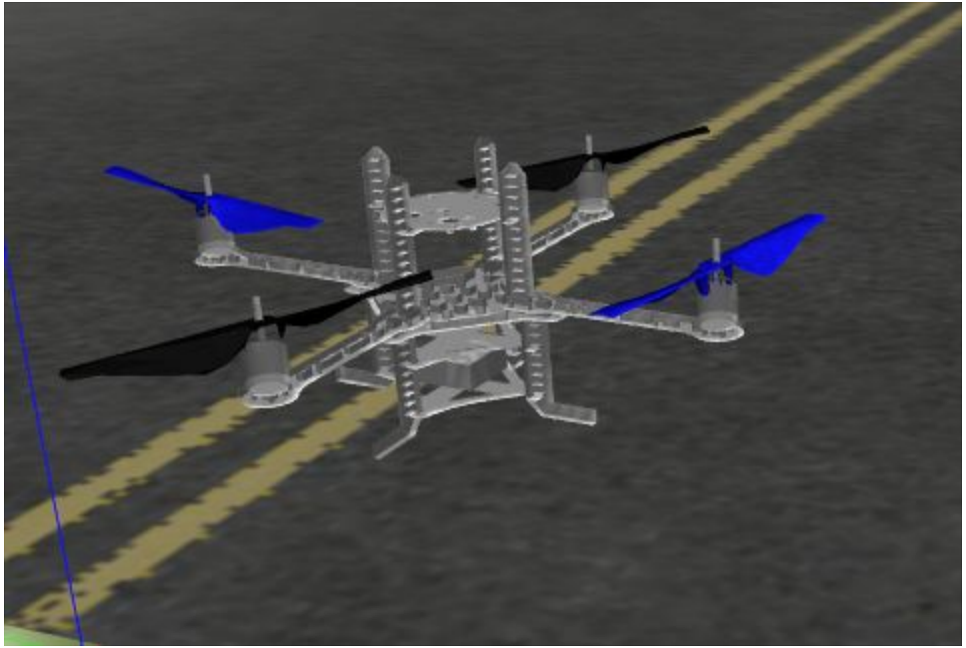
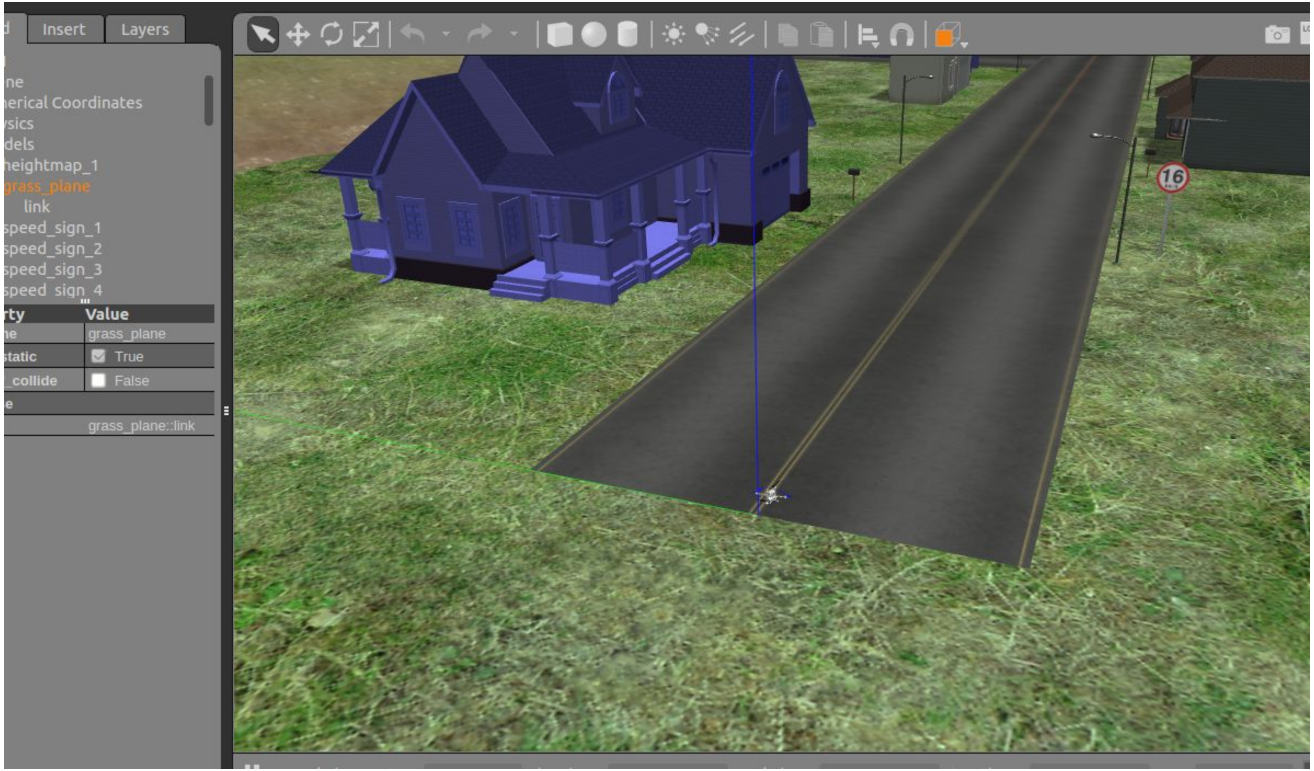


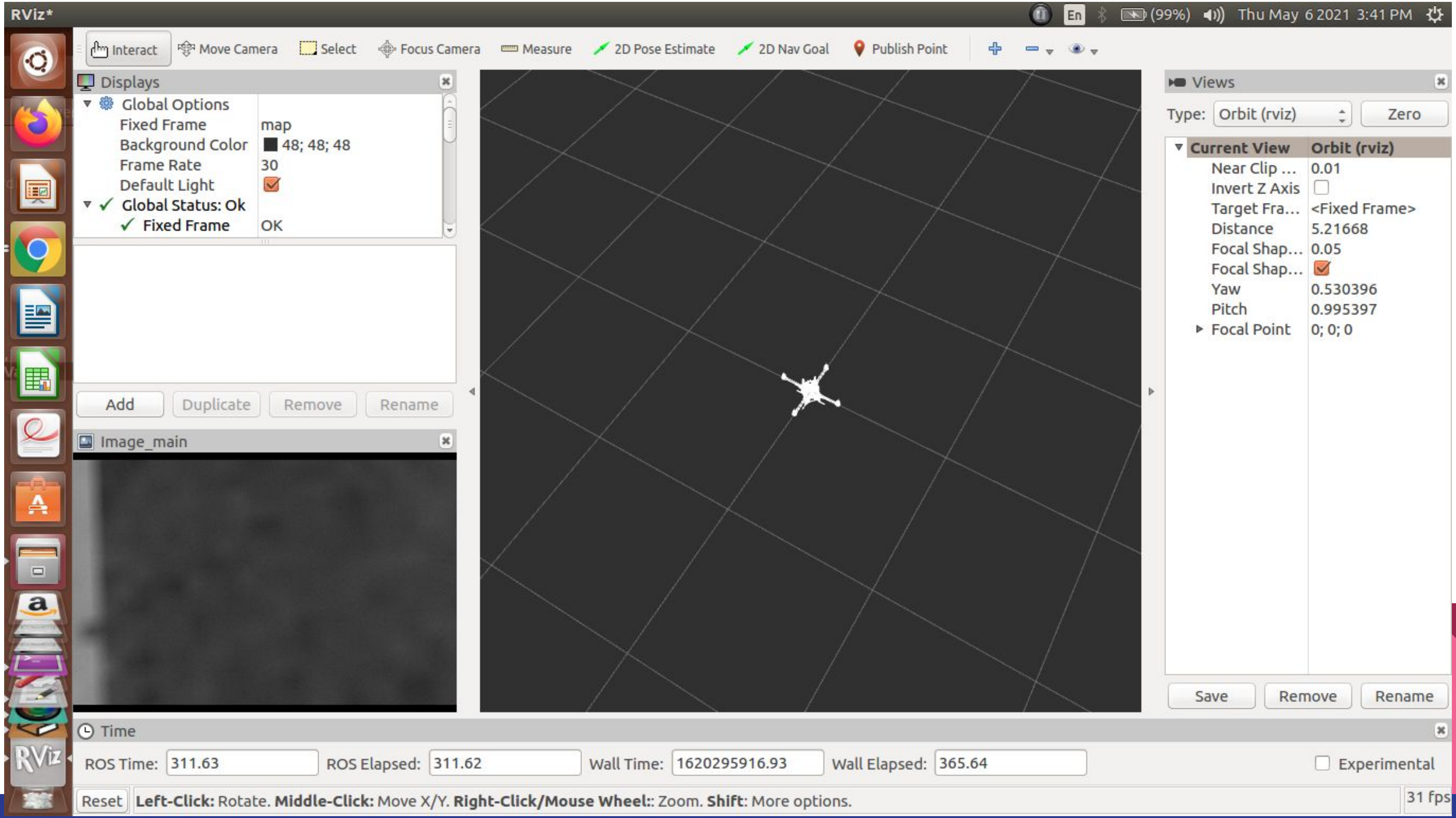
Image of the redesigned pelican drone

In the bottom is the added camera

Simulation World - Outdoors



RVIZ live feed



Simulation - Trajectory Tracking and camera live feed with wind

Trajectory points - works well with high altitude also (for visualisation purpose it is scaled down).

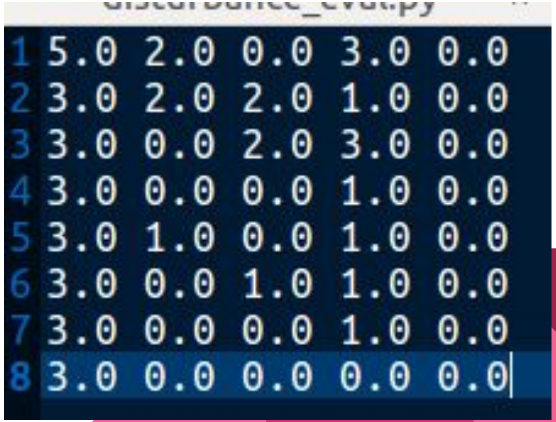
The format is time,x,y,z,yaw

Rosbag DATA:

All the data published by all the nodes or any selective topics can be stored in bag files so we can later analyse them. We got these bag files.

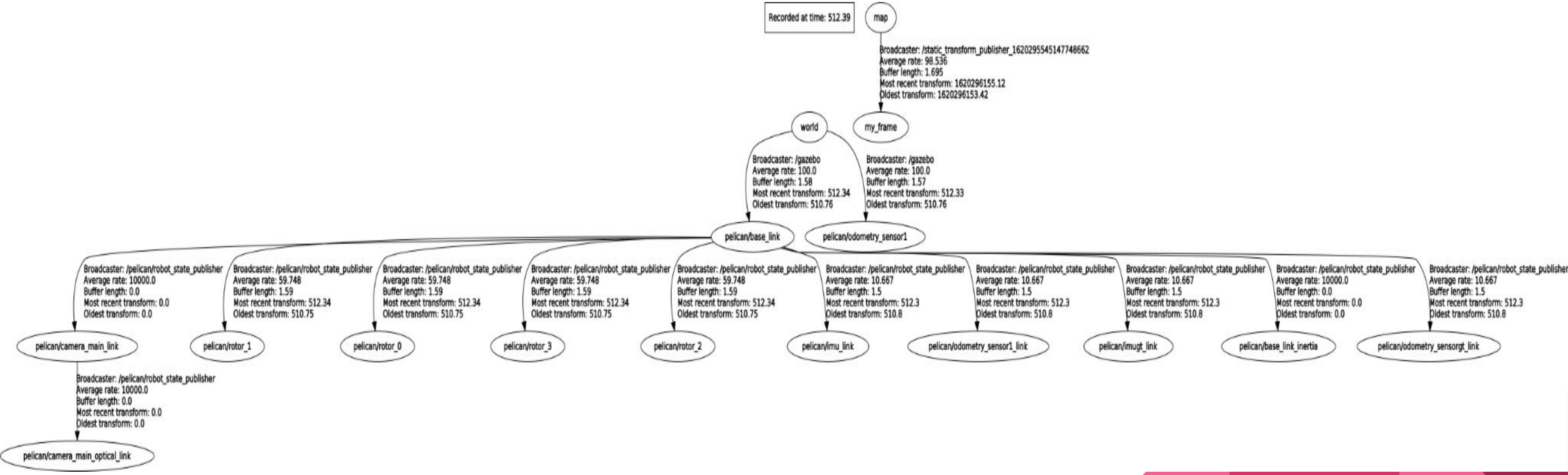
1.mkv

(play in local system)

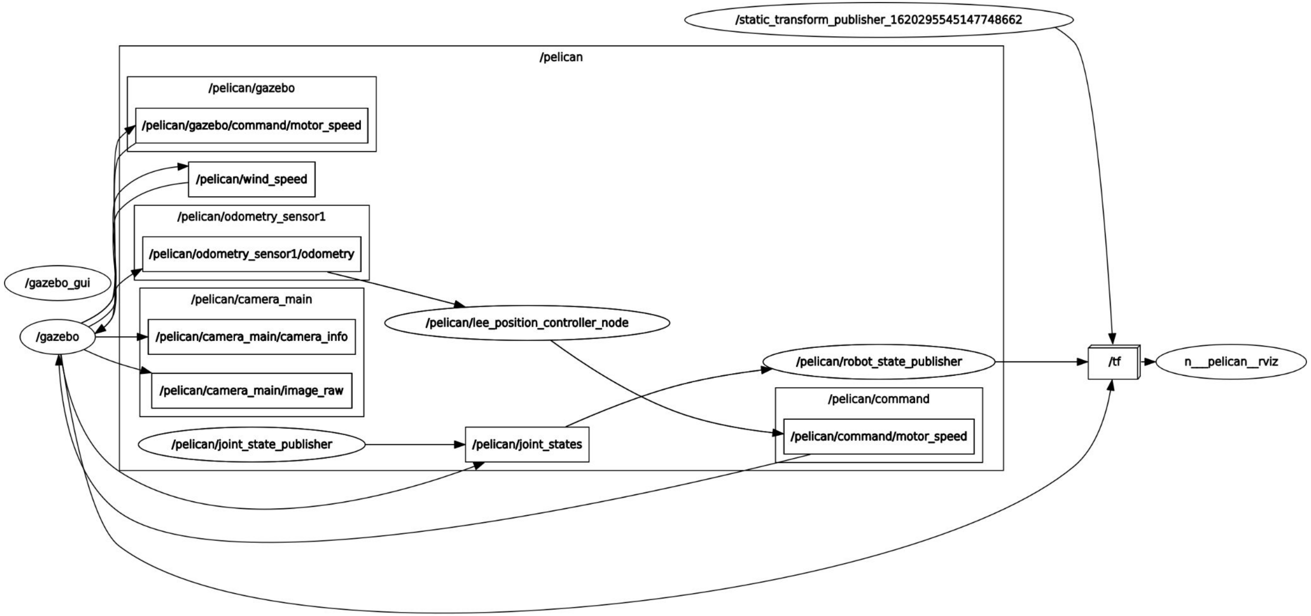


```
5.0 2.0 0.0 3.0 0.0
3.0 2.0 2.0 1.0 0.0
3.0 0.0 2.0 3.0 0.0
3.0 0.0 0.0 1.0 0.0
3.0 1.0 0.0 1.0 0.0
3.0 0.0 1.0 1.0 0.0
3.0 0.0 0.0 1.0 0.0
3.0 0.0 0.0 0.0 0.0
```

Corresponding rqt_tf_tree and rqt_graph



Corresponding rqt_tf_tree and rqt_graph



All topics list with wind

```
t [localhost:11311].  Retrying...
[ INFO] [1620288888.327960518]: Connect
ed to master at [localhost:11311]
shivani@shivani-HP-Notebook:~$ rostopic list
/clicked_point
/clock
/gazebo/link_states
/gazebo/model_states
/gazebo/parameter_descriptions
/gazebo/parameter_updates
/gazebo/set_link_state
/gazebo/set_model_state
/gazebo_gui/parameter_descriptions
/gazebo_gui/parameter_updates
/initialpose
/move_base_simple/goal
/pelican/camera_main/camera_info
/pelican/camera_main/image_raw
/pelican/camera_main/image_raw/compressed
/pelican/camera_main/image_raw/compressed/parameter_descriptions
/pelican/camera_main/image_raw/compressed/parameter_updates
/pelican/camera_main/image_raw/compressedDepth
/pelican/camera_main/image_raw/compressedDepth/parameter_descriptions
/pelican/camera_main/image_raw/compressedDepth/parameter_updates
/pelican/camera_main/image_raw/theora
/pelican/camera_main/image_raw/theora/parameter_descriptions
/pelican/camera_main/image_raw/theora/parameter_updates
/pelican/camera_main/parameter_descriptions
```

shivani@shivani-HP-Notebook: ~ 98x33

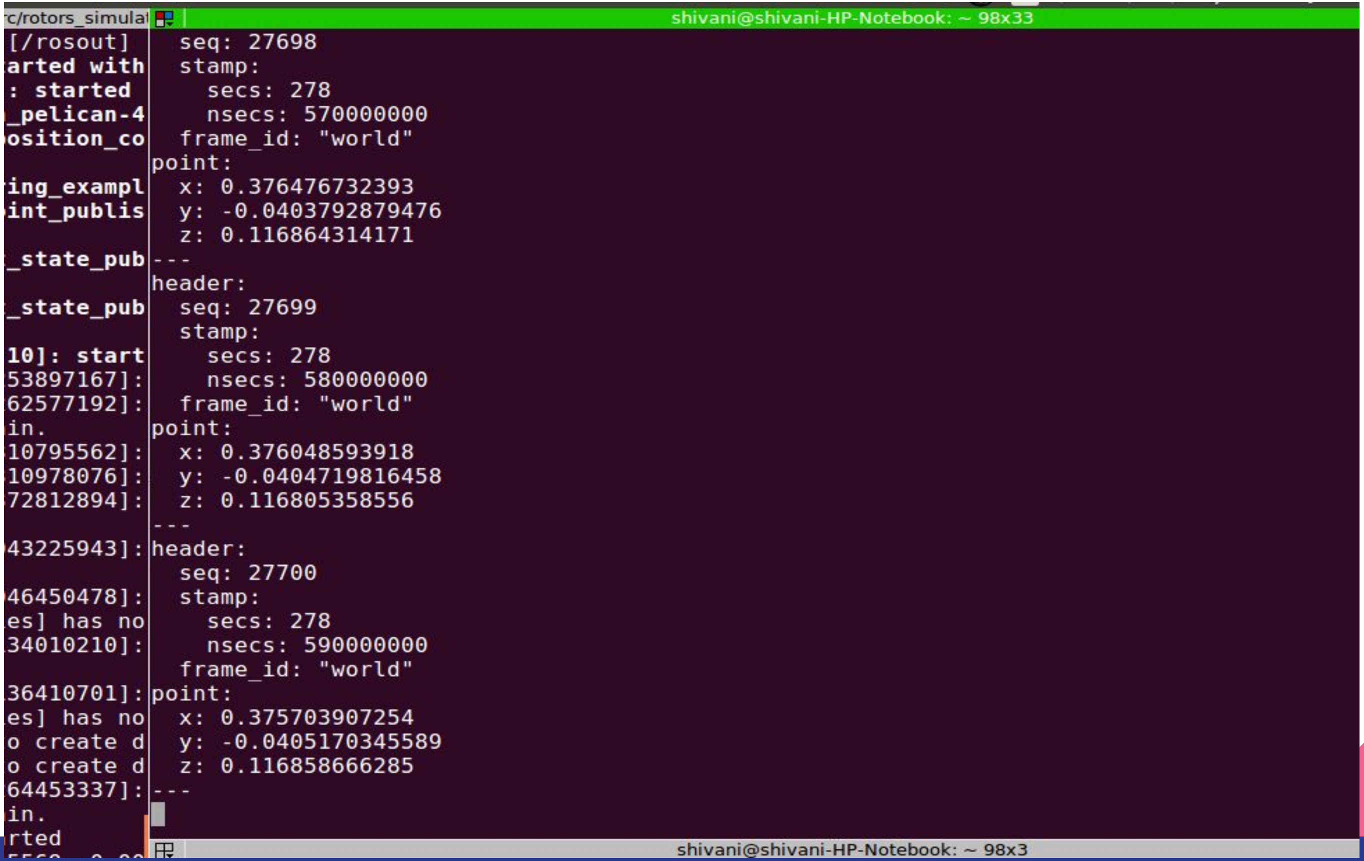
```
/pelican/camera_main/image_raw/compressedDepth/parameter_descriptions
/pelican/camera_main/image_raw/compressedDepth/parameter_updates
/pelican/camera_main/image_raw/theora
/pelican/camera_main/image_raw/theora/parameter_descriptions
/pelican/camera_main/image_raw/theora/parameter_updates
/pelican/camera_main/parameter_descriptions
/pelican/camera_main/parameter_updates
/pelican/command/motor_speed
/pelican/command/pose
/pelican/command/trajectory
/pelican/external_force
/pelican/gazebo/command/motor_speed
/pelican/ground_truth/imu
/pelican/ground_truth/odometry
/pelican/ground_truth/pose
/pelican/ground_truth/pose_with_covariance
/pelican/ground_truth/position
/pelican/ground_truth/transform
/pelican/imu
/pelican/joint_states
/pelican/motor_speed
/pelican/motor_speed/0
/pelican/motor_speed/1
/pelican/motor_speed/2
/pelican/motor_speed/3
/pelican/odometry_sensor1/odometry
/pelican/odometry_sensor1/pose
/pelican/odometry_sensor1/pose_with_covariance
/pelican/odometry_sensor1/position
/pelican/odometry_sensor1/transform
/pelican/wind_speed
/rosout
/rosout_agg
```

Sensor data

```
linear_acceleration:
  x: 0.420202253835
  y: -0.122884446892
  z: 8.91540073331
linear_acceleration_covariance: [1.5999999959603883e-05, 0.0, 0.0, 0.0, 1.5999999959603883e-05
0, 0.0, 0.0, 1.5999999959603883e-05]
---
header:
  seq: 21293
  stamp:
    secs: 214
    nsecs:  10000000
  frame_id: "pelican/imu_link"
orientation:
  x: -0.000988561054998
  y: -0.0263634685485
  z: -0.0376129273018
  w: 0.998944071494
orientation_covariance: [-1.0, -1.0, -1.0, -1.0, -1.0, -1.0, -1.0, -1.0, -1.0]
angular_velocity:
  x: -0.00125248604797
  y: 0.0266925882772
  z: 0.00146199144549
angular_velocity_covariance: [1.151923569864266e-07, 0.0, 0.0, 0.0, 1.151923569864266e-07, 0.0
0, 0.0, 1.151923569864266e-07]
linear_acceleration:
  x: 0.496220695121
  y: -0.0638489589426
  z: 8.97333538445
linear_acceleration_covariance: [1.5999999959603883e-05, 0.0, 0.0, 0.0, 1.5999999959603883e-05
0, 0.0, 0.0, 1.5999999959603883e-05]
---
```

Imu data

Sensor data



Odometry data

Sensor data


```
  seq: 712868
  stamp:
    secs: 244
    nsecs:  30000000
  frame_id: "world"
velocity:
  x: 5.0
  y: 0.0
  z: 0.0
---
header:
  seq: 712869
  stamp:
    secs: 244
    nsecs:  40000000
  frame_id: "world"
velocity:
  x: 5.0
  y: 0.0
  z: 0.0
---
header:
  seq: 712870
  stamp:
    secs: 244
    nsecs:  40000000
  frame_id: "world"
velocity:
  x: 5.0
  y: 0.0
  z: 0.0
---
```


Wind_speed data

Modelling Wind

Wind is modelled as a force acting on the drone. Details of applied wind are as follows.

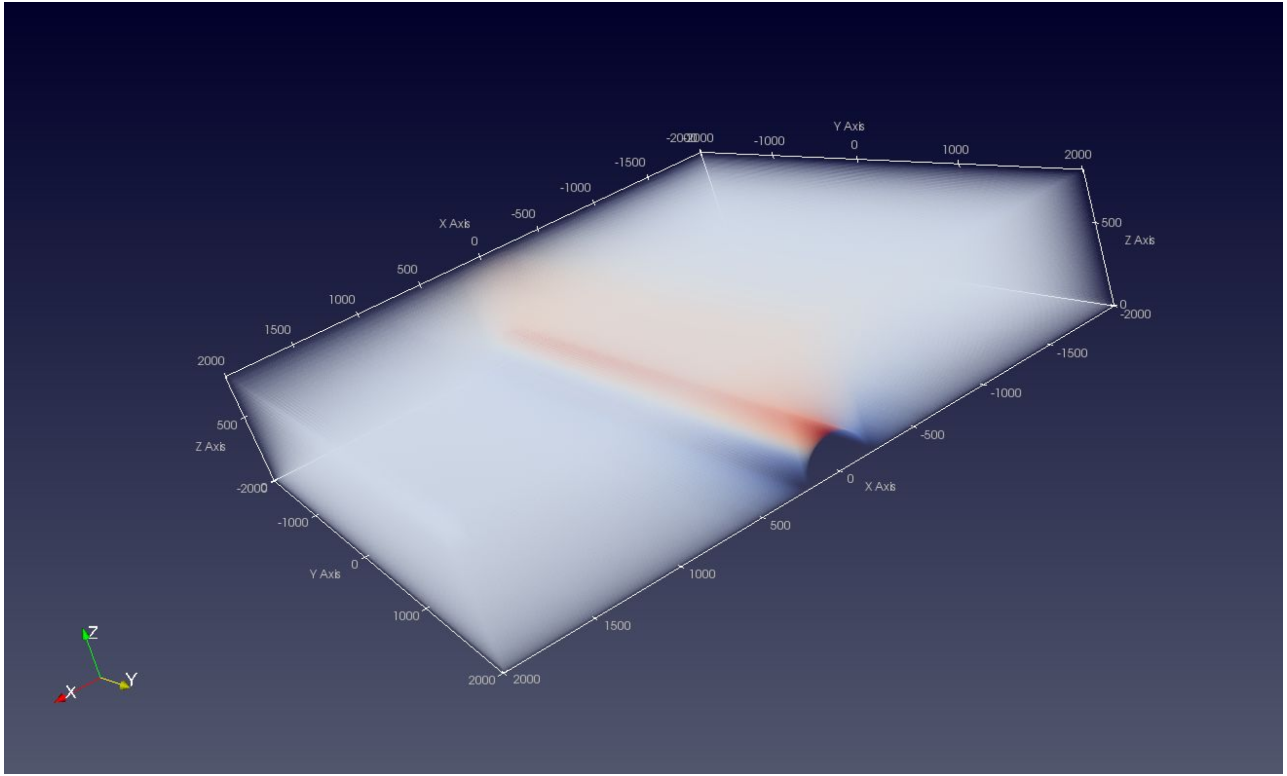
With wind we can see the trajectory tracking is erroneous but the flight is stable

The way wind is applied(or generated) is visualised in the next slide.

Two files namely, u_vis.vtu and terain.vtu are generated, which contain the wind data, resp. the terrain elevation data.

```
wind_direction="1 0 0"
wind_force_mean="1.0"
wind_gust_direction="0 1 0"
wind_gust_duration="2.0"
wind_gust_start="7.0"
wind_gust_force_mean="4.0"
wind_speed_mean="5.0"
```

Wind Visualisation - Paraview software



Simulation - Same application without wind

1.mkv -> final simulation with wind
2.mkv -> final simulation without wind (so we can compare the trajectory tracking between both the cases)

https://drive.google.com/drive/folders/1ikZXQLy3Jy2mHqT39jXujk9MYM2O331O?usp=sharing

2.mkv (play in local system)

We can see the tracking is less error prone and the drone lands at the home points correctly

References

[1] https://www.powervision.me/en/product/powereggx/specs

[2] https://www.swellpro.com/waterproof-splash-drone.html#specs

[3] https://www.propelleraero.com/blog/the-pocket-guide-to-winter-drone-surveying/

[4] https://www.dji.com/mavic-2/info#specs

[5] https://github.com/ethz-asl/rotors_simulator

[6] https://www.ros.org/

Thank you..