(A Report of a project facilitated by)

BACHELOR OF TECHNOLOGY IN COMPUTERSCIENCE & ENGINEERING

(ARTIFICIAL INTELLIGENCE& MACHINE LEARNING)

PX4 SITL With Gazebo

Submitted by:
Chitturi Madhava badari narayana

Under the guidance of

Avijith Ashe

(TEACHING ASSISTANT)

DEPARTMENT OF COMPUTER SCIENCE &ENGINEERING

KAKINADA INSTITUTES OF ENGINEERINGAND TECHNOLOGY

(Approved by AICTE & Permanently Affiliated to JNTUK,KAKINADA
and accredited by NAAC) Yanam Road,Korangi, Andhra Pradesh,pin-533461

2025-2026

Table of Contents

Week 4: Final Report and Presentation

1. Introduction

This is the final report on the implementation of the GPS failure failsafe mechanism for a quadrotor through PX4 Software-In-The-Loop (SITL) with Gazebo. The main purpose of this research was to simulate GPS failure conditions and test the response of the quadrotor against different failure conditions. Through the implementation of various failsafe mechanisms, we sought to provide the drone with the ability to switch to a stable and safe state even during GPS signal loss.

UAVs use GPS extensively to facilitate accurate navigation and autonomous flight. Real-life operations like jamming of signals, satellite interference, and GPS-denied environments could interfere with such operations and result in possible crashes or mission losses. In light of this problem, modern flight controllers like PX4 are integrated with failsafe features that can allow drones to transition into different navigation modes like Return-to-Launch (RTL), Position Hold, or Land mode. This project assesses the performance of these mechanisms in dealing with GPS failures by conducting in-depth simulations.

The experiment entailed establishing the PX4 SITL simulation setup, incorporating Gazebo for simulation purposes, and employing QGroundControl (QGC) to display telemetry data and adjust parameters. A test sequence was carried out to monitor system behavior under simulated failure scenarios. Through the logging and analysis of flight data, we evaluated critical performance metrics like stability, recovery time, and navigation accuracy after GPS loss.

The results from this research offer useful information regarding the robustness of PX4's failsafe mechanisms. The outcomes show the capability of the system to recover under GPS failure and indicate possible modifications for further improvement in terms of reliability in actual UAV applications. The report presents the process of step-by-step implementation, simulation outcomes, and important observations that aid in the comprehension and enhancement of autonomous drone security measures.

2. Abstract

Having a reliable GPS-denied autonomous quadrotor is essential for efficient and safe flight operations. This project is concerned with the implementation and test of a GPS failure failsafe mechanism on PX4 Software-In-The-Loop (SITL) using the Gazebo simulator. The main goal is to simulate GPS failures and examine the response of the quadrotor under different failure modes. Utilizing MAVLink and QGroundControl (QGC), we tracked telemetry information and measured system response under various failsafe modes such as Return-to-Launch (RTL), Position Hold, and Land mode. Through extensive simulation, we tested critical performance criteria such as stability, recovery time, and navigation accuracy after GPS failure.

The outcomes illustrate that the deployed failsafe schemes effectively avoid crash incidents and enable the proper transition to the alternate navigation modes. Yet, noted deviations in position precision and response delays indicate possible points of optimization. This report delivers a step-by-step end-to-end guide to the implementation of GPS failsafe mechanisms, including observations and recommendations for enhancing UAV robustness in real-world GPS-denied environments.

3. Deliverables

3.1 Step-by-Step Setup Guide

- Installation of dependencies

    - The software requirements are PX4-AutoPilot, gazebo (version 11 is preferable), and QGroundControl.

    - Installation of PX4-Autopilot

        - git clone https://github.com/PX4/PX4-Autopilot.git --recursive

    - After cloning repository

        - cd PX4-Autopilot

    - Install Dependencies

        - bash Tools/setup/ubuntu.sh

- Building PX4 SITL and launching simulation in Gazebo

    - Software-In-The-Loop (SITL) allows running PX4 software without actual hardware, using simulation tools like Gazebo.

    - Navigate to the PX4 folder

    - cd PX4-Autopilot

    - Build px4 for gazebo

        DONT_RUN=1 make px4_sitl gazebo

(DONT RUN command compiles without launching)

- Start the gazebo
- make px4_sitl gazebo

- Integration with QGroundControl (QGC)
    - QGroundControl (QGC) is used to interact with PX4 SITL by providing real-time telemetry, mission planning, and parameter tuning.
    - Download QGC from the official website:https://qgroundcontrol.com/downloads/
    - To run QGC ./QGroundControl.AppImage
- Connect QGC and px4 by launching QGC and pX4 simultaneously
    - ./QGroundControl.AppImage
    - Make px4_sitl gazebo
- Commands to simulate GPS failure
    - To monitor the behavior of the quadrotor while GPS failsafe and normal operation implement the GPS failsafe actions.
    - Open Qgc >Analyze tools> Mavlink Console.
    - To apply gps failsafe use px4 commands `failure gps off` .
    - By using the param set COM_POSCTL_NAVL we can set different modes like Return to Launch (RTL), Hold mode, and Safe Land.
    - 0 -> The drone will land automatically after losing GPS.

- 1 -> Return to Launch mode (The drone comes to the launch place after loading the GPS signal).

- 2 -> Hold mode (The drone remains in hold mode after losing GPS).

3.2 Simulation Scripts

- Bash scripts to:
    - Launch the simulation
        - ./QgroundControl.AppImage
        - cd PX4-Autopilot && make px4_sitl gazebo
- Introduce GPS failure
    - To introduce gps failsafe into qgroundcontrol open mavlink console which presents in analyze tools and then enter the command
      failure gps off
    - At this time the quadrotor lost its signal from the satellites and switvhes to failsafe.

- Monitor vehicle behavior
    - 1. Telemetry Analysis:
      Live telemetry data from QGroundControl (QGC) assists in monitoring altitude, velocity, and position deviations in GPS failure situations.
    - 2. Failsafe Activation Logging:
      Log monitoring from the MAVLink console guarantees that the failsafe modes (RTL, Hold, or Land) engage properly when GPS is lost.

    - 3. Stability Assessment:
      Measuring roll, pitch, and yaw angles assists in identifying whether or not the quadrotor exhibits stable flight or excessive drift and oscillations.
    - 4. Recovery Time Measurement:
      Calculating the recovery time for the drone to go from GPS loss to a stabilized mode gives a measure of how efficiently the system responds.

    - 5. Trajectory Analysis:
      Comparison of the path taken by the drone prior and post-GPS loss aids evaluation of navigation reliability as well as deviations from modeled performance.

3.3 Simulation Logs

- MAVlink and Qgroundcontrol helps in monitoring the log data and they play a crucial task in storing log data in .ulg format.During a GPS failure scenario, MAVLink messages continuously log telemetry data, including position estimates, flight mode transitions, and sensor readings. This data helps in understanding the behavior of flight in various modes and and in different failsafe actions and any defects occurred in the quadrotor or in the product.
- **Data extracted for analysis of quadrotor responses.**
  Data mined from these logs is the essential parameters of altitude, velocity, attitude, and changes in flight mode during the GPS failure episode. Through examination of this data, one may analyze the capability of the quadrotor to continue stable flight, the latency to transition to a failsafe flight mode, and any divergences from the planned course. Also testable is the response of failsafe mechanisms on board, i.e., auto-land or return-to-home (RTH) behavior. This analysis improves flight control algorithms and increases GPS-independent navigation solutions' reliability.

3.4 Analysis Report

- GPS failsafe is implemented for safety of the quadrotor. It takes place while gps lost or high variance in gps or no valid gps found.
- When a drone loses its GPS signal, it doesn’t just stop—it adapts. If it has an optical flow camera, it can track the ground to stay in place. If that’s not an option, it relies on its internal sensors, like gyroscopes and accelerometers, to estimate movement and keep steady. Even without GPS, it can maintain altitude using a barometer and IMU data, preventing sudden drops or climbs.
- If the drone can’t safely navigate without GPS, it will switch to **Safe Landing Mode**. Instead of drifting aimlessly, it gradually lowers itself and lands in a controlled manner. This can be more useful in places where GPS signals are weak, like indoors or near tall buildings.By this we can reduce the crashes and loss of drones.
- Sometimes, the GPS signal returns mid-flight. When that happens, the drone may automatically **Return to Launch (RTL)**, using its last known position to find its way back. This gives pilots peace of mind, knowing that even if GPS drops out, the drone can find its way home when the signal is restored.

- When GPS failed, the drone switched to the backup navigation. Optical flow helped to maintain position, while the IMU and barometer stabilized altitude. However, slight drifting was noticed in certain conditions.
- The **Safe Landing Mode** worked well, allowing a controlled descent when no navigation system was available. Some drift occurred in windy conditions.

4. Analysis Results

- Plots and figures showing quadrotor behavior before and after the failure.

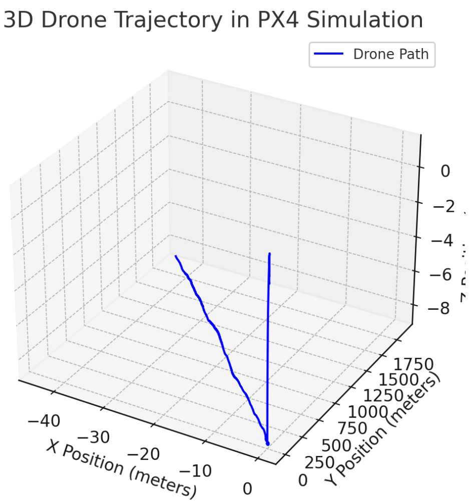
4.1 Monitoring and Logging Data

- As the simulation is done using PX4 SITL and QGroundControl the log files are saved in QGC (qgroundcontrol) and to get the data to QGC uses Mavlink.
- System response to GPS loss and transition to alternate navigation modes.

4.2 Plots and Figures to Generate

4.2.1 Position and Altitude

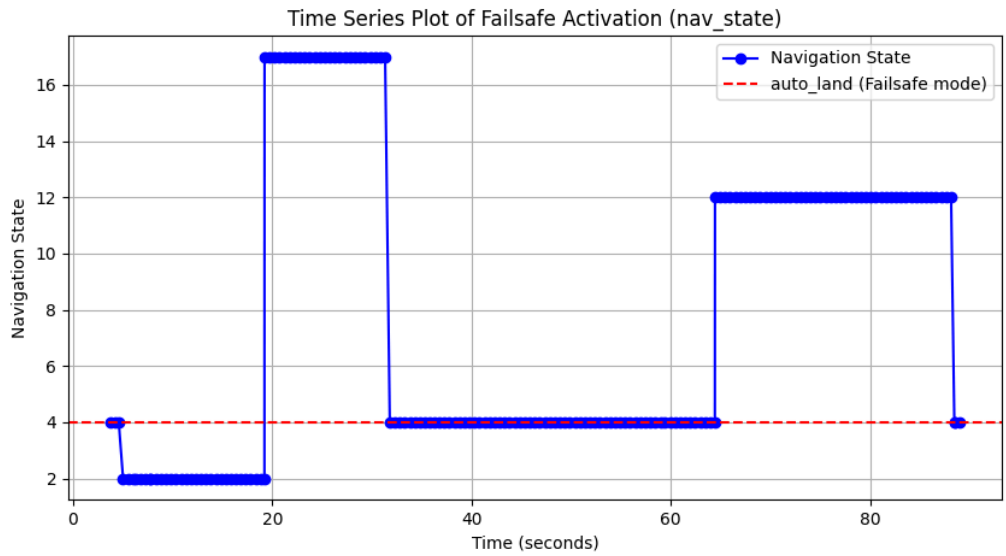
- The plot of (x, y, z) position over time to observe the quadrotor's behavior



post-GPS failure.

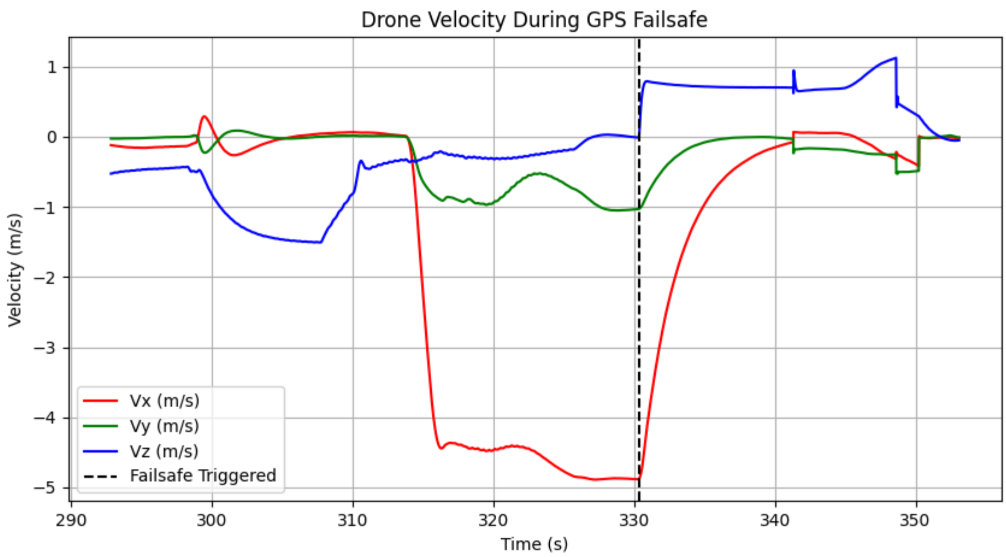
4.2.2 Failsafe Activation

- Time-series plot of failsafe status, showing transitions from GPS-based navigation to Position Hold or Land mode.



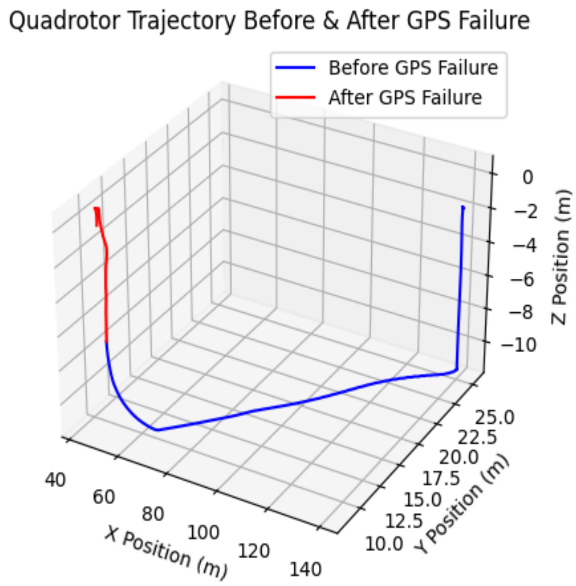
4.2.3 Velocity and Attitude

- Velocity plots (vx, vy, vz) and roll/pitch/yaw angles to analyze stability during GPS failure scenarios.



4.2.4 Trajectory Analysis

- 3D trajectory comparison of the quadrotor in Gazebo before and after GPS failure.



4.2.5 Comparison of Normal and Failure Scenarios

- I observed changes in stability, recovery time, and navigation accuracy before and after GPS failure.

- **Stability**

  1) During normal operation, the quadrotor flies very stably and smoothly.

  2) While in GPS failsafe mode, sudden changes in velocity lead to uncontrollable instability.

- **Recovery Time**

  1) In Normal operation, while the drone goes to land mode it can recover within the time range of 2 to 3 seconds.

2) While in GPS failsafe operation, it would take a minimum of 10 seconds to recover the lost signal.

- **Navigation accuracy**

1) Obtained accurate position based on GPS + sensor fusion.

2) Position drift occurred on other sensors (barometer, IMU).

5. Conclusion

- The simulation successfully demonstrated the GPS failure failsafe in PX4 SITL, which confirmed its capability to maintain the drone stablility and avoid crashes. Although the system worked well, there is improvement in response time and after-failure navigation accuracy. Tuning the parameters will improve the reliability of the drone, making it more robust in real life situations where GPS loss can happen suddenly.

- The simulation was able to test the GPS failure failsafe in PX4 SITL,by keeping the drone stable and preventing it from crashes. The switch to backup navigation was effective, maintaining control of the drone. Additional improvements in response time and accuracy can make the system even more robust in actual situations.