Environmental Perception Using Simulation for Drone Applications

Objective

The goal of this project is to develop and simulate an environmental perception system for drones. This project will integrate several technologies and tools including Dronekit, STIL, Python, OpenCV, Gazebo, SLAM (Simultaneous Localization and Mapping) with depth cameras, PX4 flight controllers, MAVLink, MAVLink gateways, and AI tools for person and plant detection. Students will transition their simulation-based solution to a physical drone equipped with PX4, a USB camera, depth sensors, and an optical flow sensor.

Key Components and Tools

1. **Dronekit**:
    - For drone control and autonomous mission planning.
    - Provides Python API for MAVLink communication.
2. **Python and OpenCV**:
    - Python for scripting and tool integration.
    - OpenCV for computer vision tasks like object detection and feature matching.
3. **Gazebo Simulator**:
    - Physics-based simulation environment for testing drone systems.
4. **SLAM with Depth Cameras**:
    - SLAM techniques like ORB-SLAM2 for mapping and localization.
    - Depth cameras to provide real-world 3D data.
5. **AI Tools for Detection**:
    - Implement AI models using TensorFlow or PyTorch for detecting persons and plants.
    - Train and deploy detection models in both simulation and real-world setups.
6. **PX4 with MAVLink and MAVLink Gateway**:
    - PX4 as the flight control software.
    - MAVLink for communication between the drone and the ground control station (GCS).
    - MAVLink gateway to relay communication between simulation and real-world setups.
7. **STIL (Software In the Loop - SITL)**:
    - To enable integration of simulation and real-world systems in the testing and development process.
    - Facilitate the testing of algorithms and communication protocols in a simulated environment before deploying to physical hardware.

Methodology:

1. Literature review: study fundamental concepts of SLAM, MAVLink protocols, Dronekit, and AI-based detection systems.

2. Tool familiarization: install and configure Gazebo for drone simulation. Learn and experiment with Dronekit for mission scripting. Set up and utilize OpenCV for object detection tasks. Train and test AI models for detecting persons and plants. Do simulation setup by create some simulation scenarios, such as obstacle-filled areas and environments with persons and plants. Implement SLAM algorithms using depth data from the camera and visualize the generated map in real-time.
3. Protocol Stack Integration: implement MAVLink protocols for drone-to-GCS communication. Configure a MAVLink gateway to bridge the simulated environment with the PX4 autopilot.

Deliverables:

1. Software environment: an image of the entire software environment with Gazebo. Python scripts for Dronekit, OpenCV tasks, SLAM, and AI detection.

2. Reports: Detailed documentation of methodologies and results.