2D LiDAR based Aerial Navigation

Project Description
The goal of this project is to perform autonomous aerial search and rescue in an outdoor environment. We have developed an unmanned micro aerial vehicle that will navigate, explore, avoid obstacles, detect a subject of interest and rescue the subject autonomously in an unstructured and unknown outdoor environment.

Mission Outline
1. Tele-operated take-off from the start location
2. GPS based autonomous navigation to the destination
3. Scan region for obstacles in forward motion.
4. Recalculate trajectory
5. Traverse obstacle-free trajectory
6. Detect the subject using image processing
7. Deploy Lift Mechanism
8. Navigate to the destination point and loiter

Functional Design

Controls Simulation
- Quadrotor Dynamics model
- Calculates the required velocities and acceleration

Hardware-in-Loop Simulation
- Xplane based HIL Simulation
- Incorporates onboard control algorithm

PID Tuning
- PID Control for roll, pitch, yaw and altitude
- Nested PID control on each axis: rate and stabilize

Software Development
- High-level controller developed in ROS
- Message-passing mechanism between nodes

Communication
- MAVLink protocol
- Wireless Communication: Arduino <-> ground station
- Wired: Arduino <-> On-board computer

Ground Control Station
- Developed based on GTK++, OsmGpsMap and CCNY GCS.
- Display: UAV status, flight path and waypoints
- Provision for user input

Key Functionalities

Stable Flight
- Controllable tele-operation
- Autonomous waypoint navigation

Rescue Mechanism
- Integrated with the visual servoing and altitude hold
- Support tele-operation

Integrated System

Optic Flow:
- Shi-Tomasi Feature Detection
- Lucas-Kanade Optical Flow

Subject Detection:
- Red color detection
- Threshold Hue value in HSV space

Image Processing

Altitude Perception
- The mirror reflects the laser beams vertical to sense the altitude
- Achieved an accuracy of 3cm

Issues
- Vibration challenges the quality of hardware
- Large payload shortens the life of the motor
- The compass got corrupted by the magnetic field of other devices
- GPS error leads to bad odometry
- LiDAR performance got affected by the bright sunlight

Key Activities:

Quadrotor Frame
1. Aluminum arms
2. Carbon fiber mounting boards & landing gears
3. Motor to motor distance = 25.5 cm

Software Framework
1. Arducopter open-source firmware for low level motor control
2. MAVLink communication protocol developed in-house
3. ROS framework for perception & navigation

System Design

On-board Electronics
1. ArduPilot Mega Board: Atmega 2869 microcontroller
2. IMU Shield/ Oil Pan: contains gyroscopes, accelerometers, magnetometer & barometer
3. LiDAR: Hokuyo URG-04LX UT01
4. GPS receiver
5. USB camera
6. DC Motors: 880kV
7. Electronic Speed Controllers
8. Single Board Computer: RPiC2
9. Xbee transmitter

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