Autonomous Navigation, object detection and retrieval in an Indoor Environment.

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Abstract

The paper deals with the control and navigation for the autonomous aerial vehicle (UAV) in an Indoor (as GPS is denied) environment. The solution splits the problem into 3 modules being: Vehicle Operation, Navigation and path planning, Image Processing. The three operations are performed simultaneously to achieve indoor flight.

INTRODUCTION

We present our solution for navigating, exploring and locating of objects in unknown indoor environment. Most UAVs use GPS to navigate and hence the problem is more challenging as the GPS is denied. Indoor navigation can be extremely useful in search and rescue operation and surveying of dangerous areas that humans do not have access to. Aerial platforms can also be deployed quickly and are able to traverse various terrains that would not be possible with conventional land robots.

PROBLEM STATEMENT

The 6th Mission requires the aerial vehicle to:

1. Enter a building through a 1m x 1m opening.
2. Scan the area for a flash disk.
3. Retrieve the flash disk.
4. Replace with duplicate flash disk.
5. Exit the building.

The above should be completed in less than 10 minutes and without triggering any alarm or landing even for the briefest period of time.

Conceptual Solution

The Aerial Vehicle is an AR Drone 1.0 (Parrot) quadrotor. The drone was chosen for its features such as safety, low weight, flight time and stability.

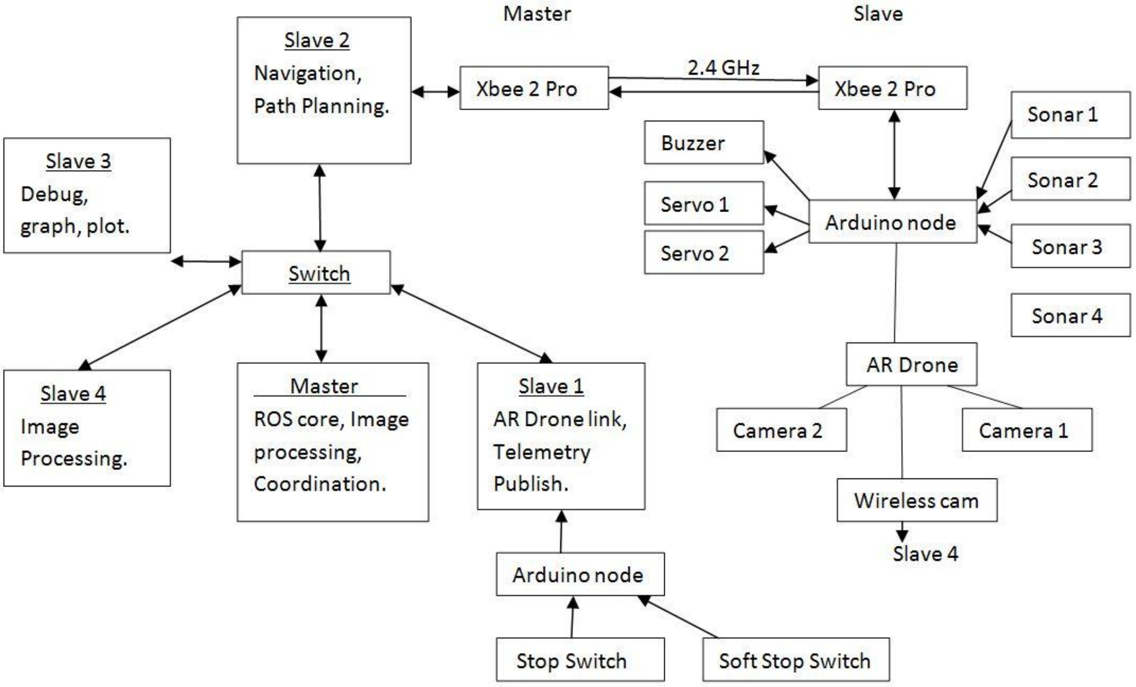
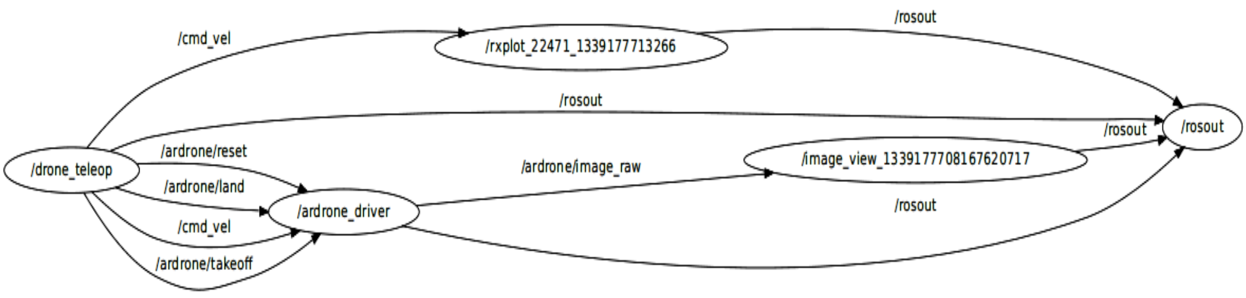


Figure 1: Overall system architecture

A cluster of computers is used to break down the entire task into subtasks. Each component is assigned a particular job. The Master is responsible for Image processing, ROS core controls and coordination. Slaves are created where one of them controls AR Drone link, telemetry publish, another for image processing, for navigation and path planning and for debug and plots. Xbee 2 pro is used for communication among the components.



The AR Drone Brown package is used to connect to the AR Drone. This package consists of the SDK from Parrot with a ROS wrapper. The Drone teleop package is used to issue commands to the drone. The commands that can be sent are a) Take off/land b) Forward, Backward, Left and right. c) Rotate left and right. d) Increase/decrease altitude e) Toggle emergency state. The commands sent to the quadcopter from the teleop node are subscribed to by both the ardrone_driver and rxplot. The driver sends commands to the quadcopter and rxplot plots the values in a value vs. time graph that is used to monitoring and debugging. Additionally these messages can be sent to a logging node to create a bag file for later review. The ardrone_driver node publishes the raw camera feed and the telemetry data coming in from the drone. This is used by other nodes for path planning and navigation.

Mission Planning

SONAR is used as a primary sensor for navigation. Four SONAR devices are deployed on four directions of the drone which provide nearest distances in the respective directions and the camera along with this acts as the bots vision. The navigation and path planning involves a logic where the environment is considered as a 3 dimensional cube. As and when the drone moves, logical cube regions are added into the traversed path. The entire operation is divided into a set of states. The entrance through the window may be considered as the initial one. After this is achieved a transition to the next is made where it switches into the object search operation, sign board location and parsing and laser barrier detection states. After the operations are carried out and the object is retrieved, the vehicle traces back the path to the window entrance using the reverse path mapping mechanism.

Flight Termination

Two kinds of kill switches are implemented. The soft kill involves sending a terminate command to the quadcopter through the external system. Another kill mechanism is implemented where the system is forced into an emergency state causing the operations to halt and the vehicle to immediately land.

Image Processing and Target Identification

The detection of the camera (blue LED) for a covert entry is performed using a simple blob detection mechanism by setting a suitable threshold. Object detection is done by detection and selection of key features of the sample and matching with a reference. The key points for an object are extracted to provide a feature description of the object. This description, extracted from the image, can be used to identify the object in a sample containing many other objects. The object recognition can be made more reliable if the extracted features are detectable even under change in image scale, noise and illumination. Such features can be found in high contrast regions of the object such as the edges. The relative position between the features must remain constant in the original image and the sample.

The signboard detection is done by extraction which forms an object description. The description is matched against a reference to identify the signboard. Similar mechanism is utilised to identify and deactivate the laser barrier.

Threat Avoidance

Threats are detected and avoided by using the input from the cameras and sonar. These detected threats are then mitigated by adjusting the quadcopter suitably. Most threats can be thwarted either by moving over or under them or by moving away from them. The laser barrier presents a major threat and we intend to have the quadcopter attempt to disable it but if that fails, it will fly between the lasers so as to avoid triggering it.

Communication

The communication among the components of the system comprises of: A LAN connectivity among all the components that form the cluster which is responsible for processing, a wireless Wi-Fi communication link between the cluster of computers and the quadcopter and A 2.4 GHz bandwidth channel between the quadcopter and the cluster of components.

PAYLOAD

The quadcopter is outfitted with Xbee, Microcontroller, 2 servos, Magnetic pickup mechanism and 4 SONARS. Xbee ensures a 2.4 GHz connectivity channel between the quadcopter and the external system. The Microcontroller acts as another ROS node which publishes the SONAR data and subscribes to the servo state. The computation data is sent back to the external base station and the external system sends operational information to the quadcopter.

Vehicle Monitoring

During the entire operation of the quadcopter, the vehicle is constantly monitored by extensive use of GUI's. The telemetry (linear and angular velocities, altitude, and battery state) information is plotted as value against time graphs. Raw image data and the Image processing results are shown in separate windows. The sonar values are shown using the rviz package on ROS.

Flash disk Pick and Drop off Mechanism

A Magnetic mechanism is used to pick the flash disk. The duplicate flash disk is dropped off by the release mechanism that is servo actuated. Another servo is used to secure the flash disk picked up by the magnets.

OPERATION

Flight Preparation

Before each flight the battery levels are checked. The propellers are inspected for signs of wear and tear. Also the quad is inspected for signs of damage. The wireless links and the communication among components are tested.

Checklist

1. If all screws are tightened.

2. If the propellers and motors are mounted securely.

3. If the propeller guards are secured tightly.

4. If all the connectors are in place and oriented right.

5. If the battery is completely charged.

6. If the remote link, manual override and kill switch are functioning.

7. If the quadcopter is perfectly level for the sensors to calibrate.

Conclusion

The aerial vehicle is capable of autonomous navigation in an unknown environment. We have developed a set of algorithms that account for the unique characteristics for operation and path planning using the sensors on board.

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