GUJARAT TECHNOLOGICAL UNIVERSITY

Chandkheda, Ahmedabad

Affiliated

Babaria Institute of Technology

A

Project Report

On

QuadDrop

Prepared as a part of the requirements for the subject of

PROJECT - I

B. E. IV, Semester – VII

(Computer Science and Engineering)

Submitted by:

Group:

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(2019-2020)
Academic year
A

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Guided by
Prof. Shweta Rajput

Prepared by

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CERTIFICATE

This is to certify that the project report entitled **QuadDrop** is prepared and presented by **Ninad Choksi, Krut Chitre, Aditya Narayan Bhattacharya, Walstan Baptista** bearing Enrolment Nos. 160050107011, 160050107510, 160050107506, 160050107503 respectively 4^{th} Year of **B.E (Computer Science & Engineering)** and their work is satisfactory.

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Prof. Shweta Rajput	Dr. Avani R. Vasant
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Date: 09/10/2019

Name of Guide

Signature of Guide

1) Introduction

1.1) Problem Summary

Today the world depends heavily on online shopping. Expecting product drop offs at our doorsteps is a convenience the world has adopted widely. But there is a big drawback in the current end mile delivery system. It is slow.
We may see our package out for delivery in the morning and it may not arrive till the evening. This is especially true in bigger cities. The culprit here is none other than the traffic.
Project QuadDrop aims to skip the traffic for your packages which will arrive by air. We aim to deliver packages on quadcopters within the city. The obvious benefit is speedy delivery and accurate timing on when a package will be delivered.
This has benefits for both the customer and the seller. The seller is able to move more packages every hour with greater cost efficiency, and the customer never has to wait an entire day guessing when the delivery will be made.

1.2 Aims and Objectives

The systems main functions include; automatic sorting of packages and selecting those which can be delivered by air.
It will also find the most efficient route for each of the drone.
The main system also interfaces with the customers to let them know when their package will arrive and also lets them negotiate timings if possible.
There shall be functionalities to keep track of the performance and health of each drone and the system shall notify the servicing crew if any drone needs maintenance.
The scope of the project consists of but is not limited to:
Delivering light weight products to specified locations
Authenticate proper addressee with QR codes
Delivery in difficult to access areas.
Delivering emergency services (medical kits, food packets etc.) to disaster affected areas.

1.3 Problem Specification

In these fast times the conventional delivery systems nowadays are considered slow.
Everyone wants what they had ordered delivered to them really fast.
Final delivery may take more time and may have uncertainty of when the item will be delivered. Factors like traffic come into play.
The delivery person may also make some mistake in driving to the address and may delay the delivery by some time.
We may see our package out for delivery in the morning and it may not arrive till the evening. This is especially true in bigger cities. The culprit here is none other than the traffic.
Due to the uncertainty in the time of delivery the customer has to wait at home anticipating the delivery. This is a waste of time if the customer had to go somewhere else.
There are also some places where road access is restricted. In those places, delivery by our conventional methods is not possible.

To overcome this wait and restrictions, the medium of delivery, if changed can bring about a revolution in the delivery business and its cost efficiency.

1.4 Literature Review

Patent Search:

This disclosure describes an unmanned aerial vehicle ("UAV) configured to autonomously deliver items of inventory to various destinations. The UAV may receive inventory information and a destination location and autonomously retrieve the inventory from a location within a materials handling facility, compute a route from the materials handling facility to a destination and travel to the destination to deliver the inventory. After ordering some products from digital marketing users cannot track the delivery once it is "out for delivery". Customer might be waiting for a delivery with status "out for delivery" in morning but gets delivered in evening. this problem can be solved by live tracking and fast delivery due to areal route (avoiding traffic jams). After ordering some products from digital marketing users cannot track the delivery once it is "out for delivery". Customer might be waiting for a delivery with status "out for delivery" in morning but gets delivered in evening. This problem can be resolved due to live tracking and no traffic jams due to areal route.

1.5 Plan of Work

The project's development has been divided into phases as stated below:

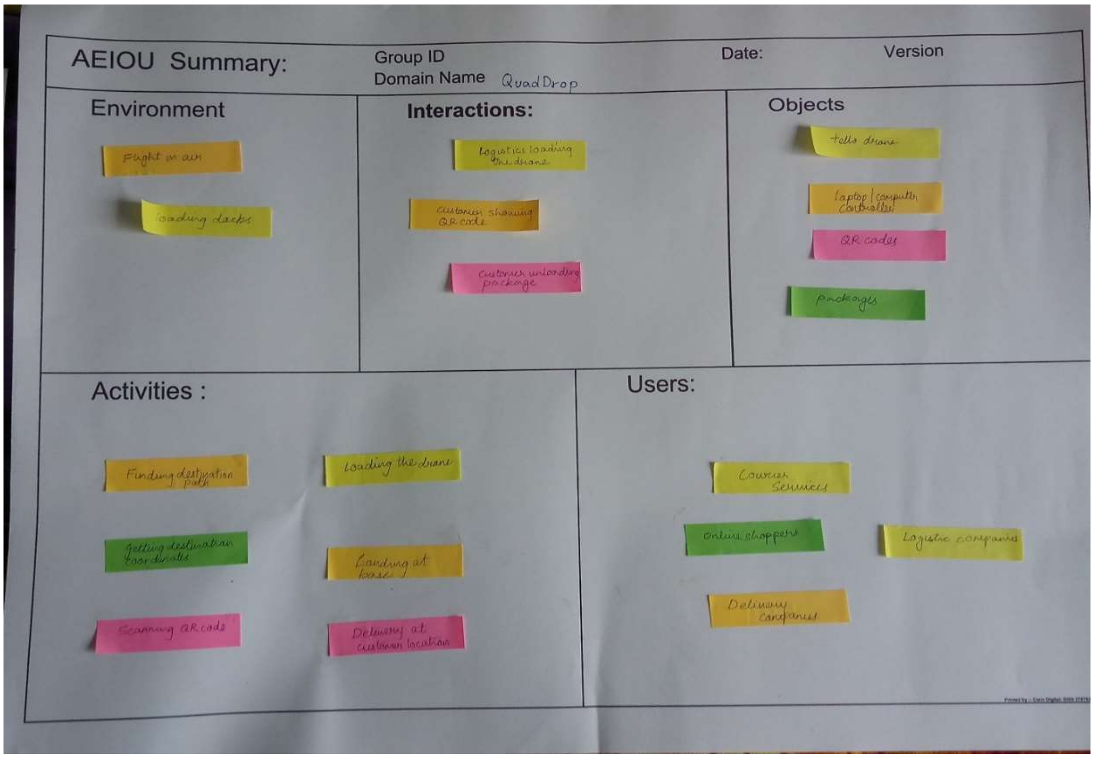
- Information gathering from external sources.
- Selecting the proper hardware (drone) for our specific requirements (i.e. size of drone, payload size, distance covered etc.)
- Creating a proper algorithm for selecting the optimal path for the drone (consists of finding the shortest path for the drone from source to destination, avoiding no fly zones and selecting which payload to drop off first).
- Interfacing the drone with the device by which it has to take commands (here computer).
- Implementing a coordinate system for locating the drone in flight (here WhyCon).
- Tuning the PID of the drone for in flight stability and automatic error control.
- Accuracy testing and fine tuning the drone flight error controls to manage external factors like wind.

1.6 Materials and Tools Required

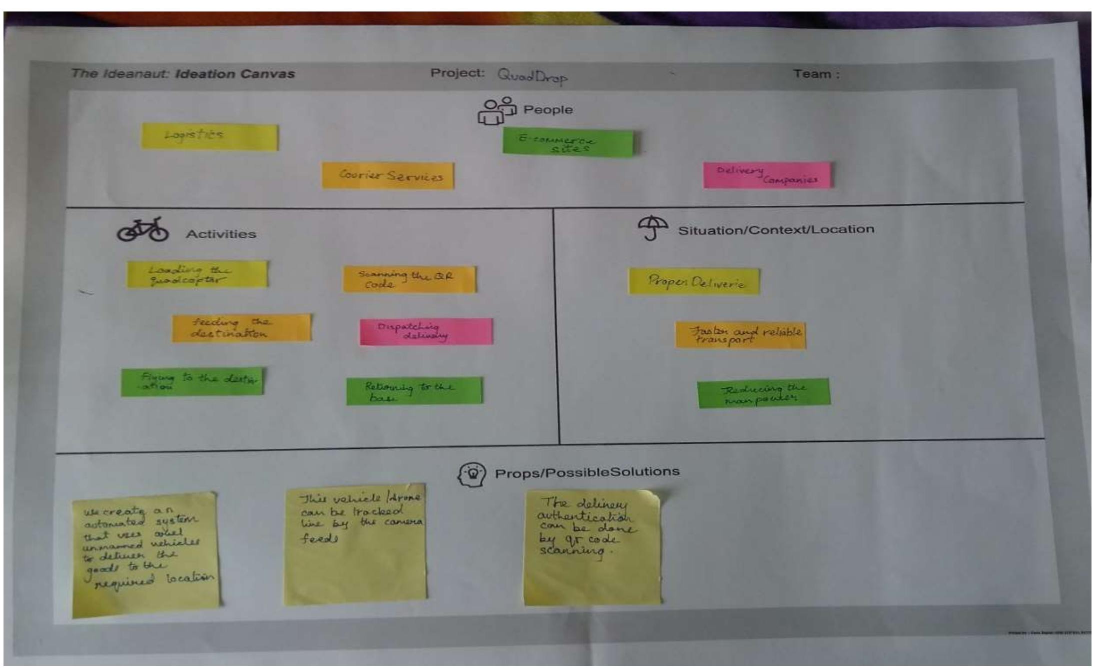
Drone Used: DJI Tello
Development language: Python
Platform used: Robot Operating System on Ubuntu 16.04
Libraries used: OpenCV, Numpy, ROSpy, Whycon, Tellopy
Other hardware requirements: Whycon camera, Computer (minimum Intel Core i5 recommended)

2) Analysis, Design Methodology and Implementation Strategy

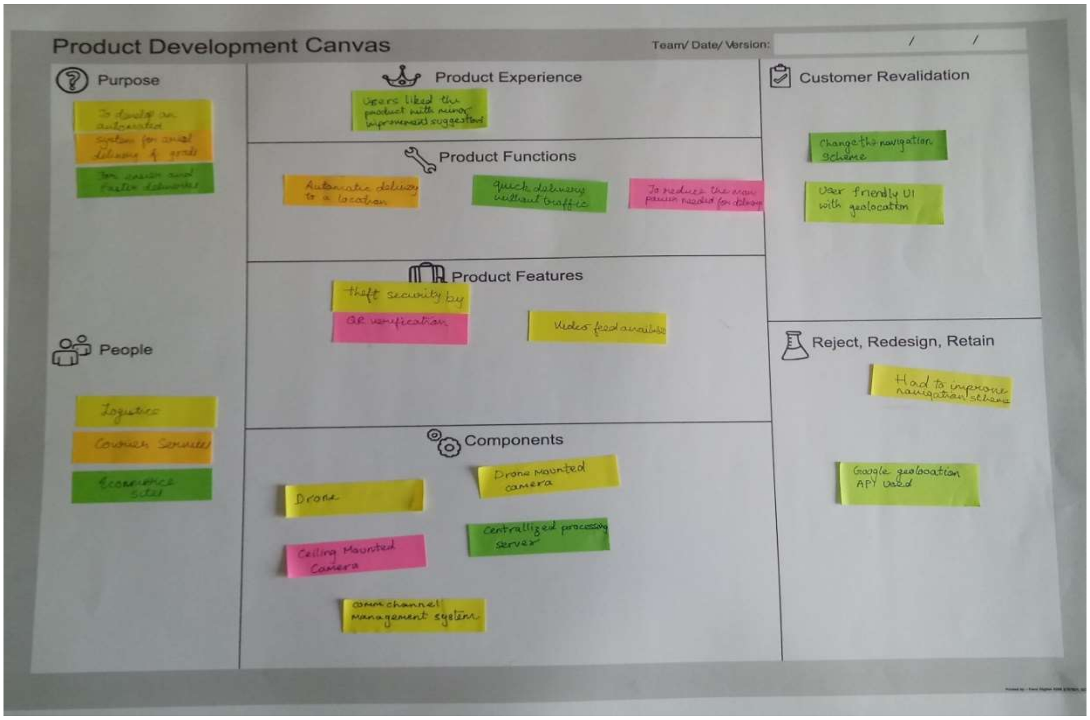
2.1) Observation Matrix (AEIOU Summary)



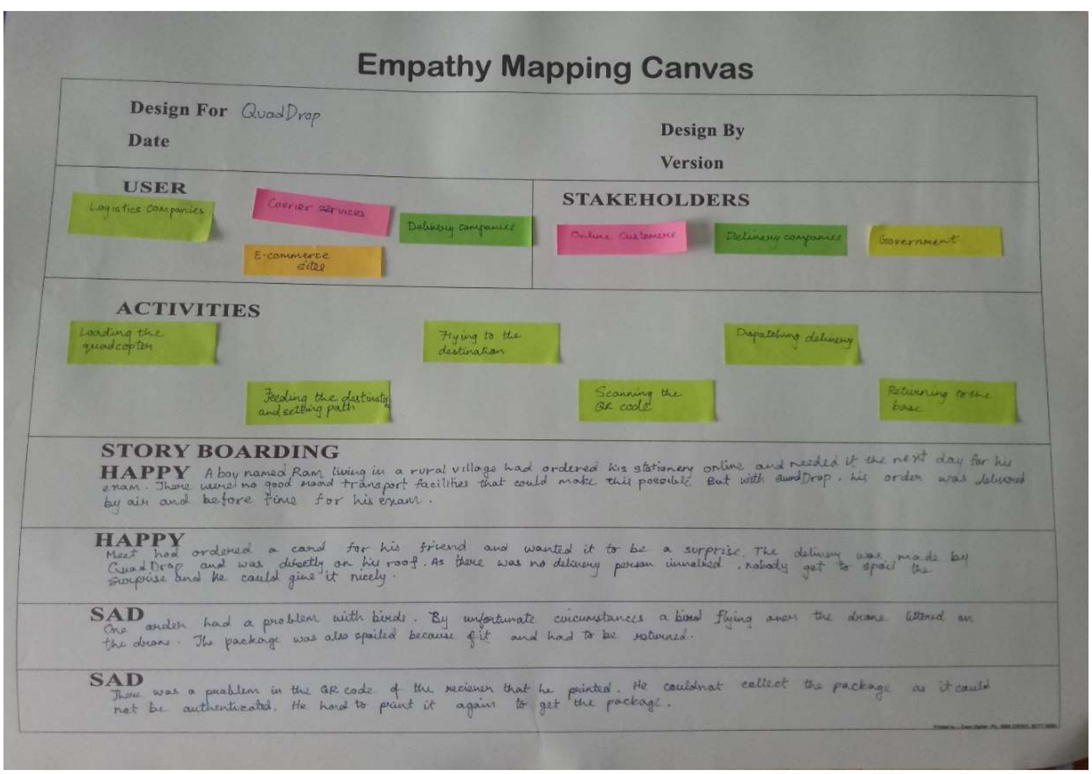
2.2) Ideation Canvas



2.3) Product Development Canvas

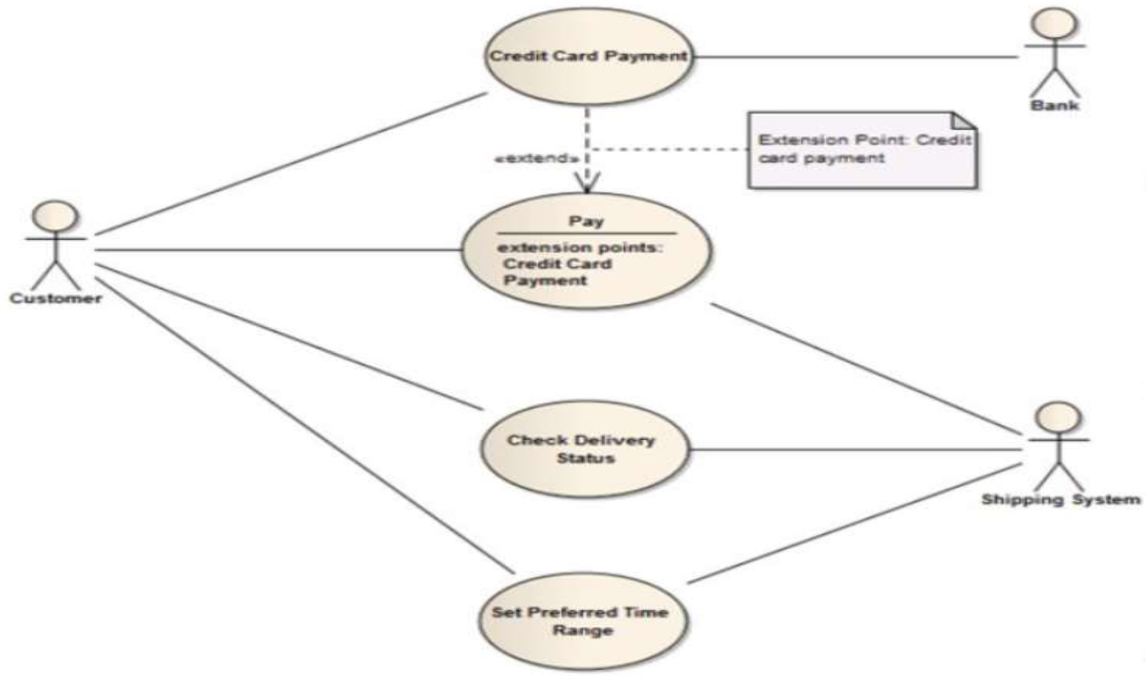


2.4) Empathy Mapping Canvas

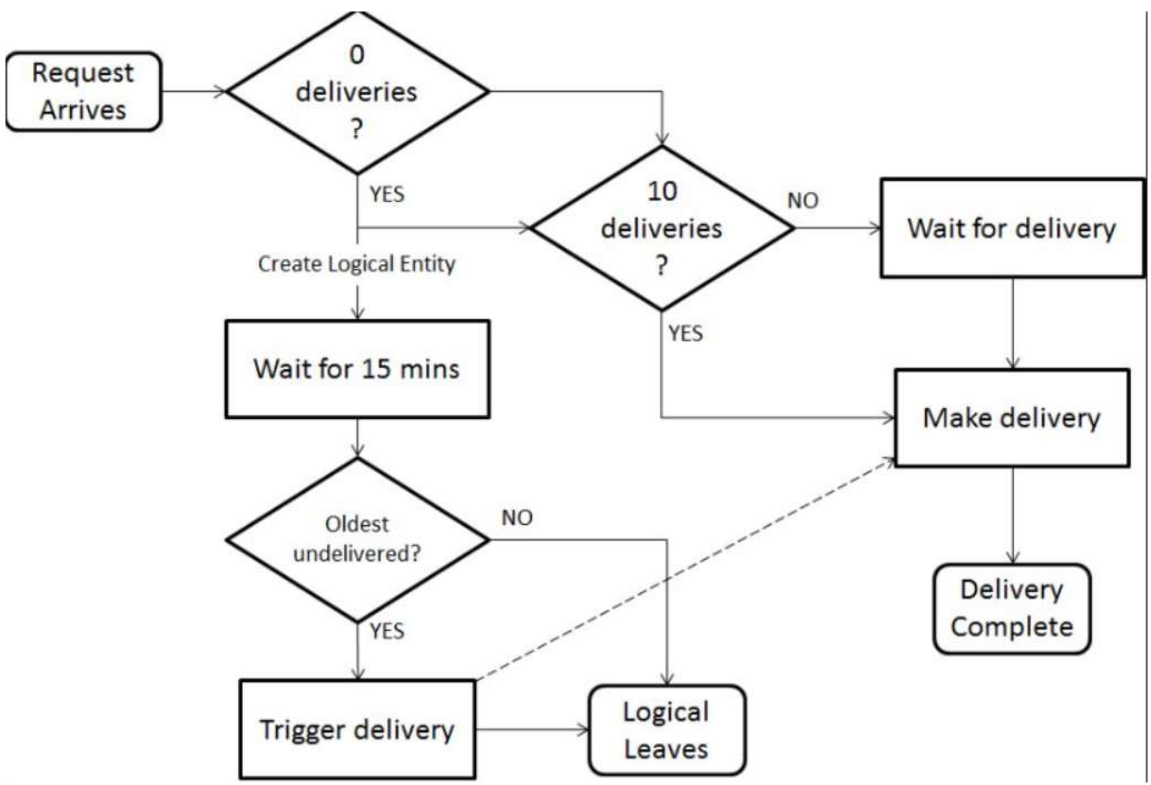


2.5) Diagrams

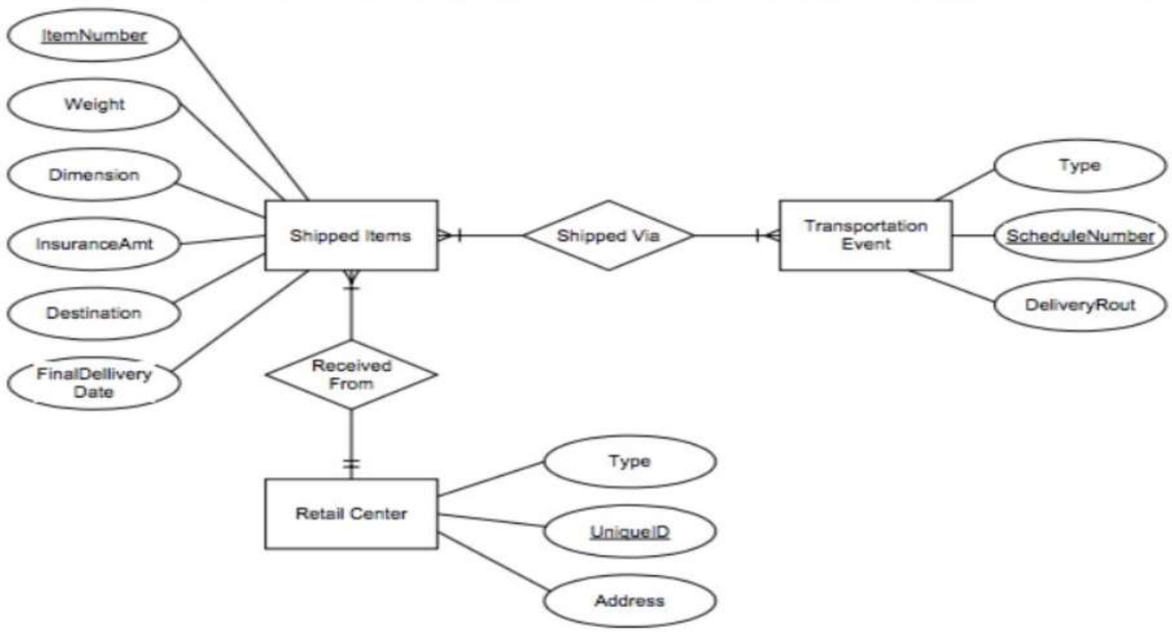
2.5.1) Use Case Diagram



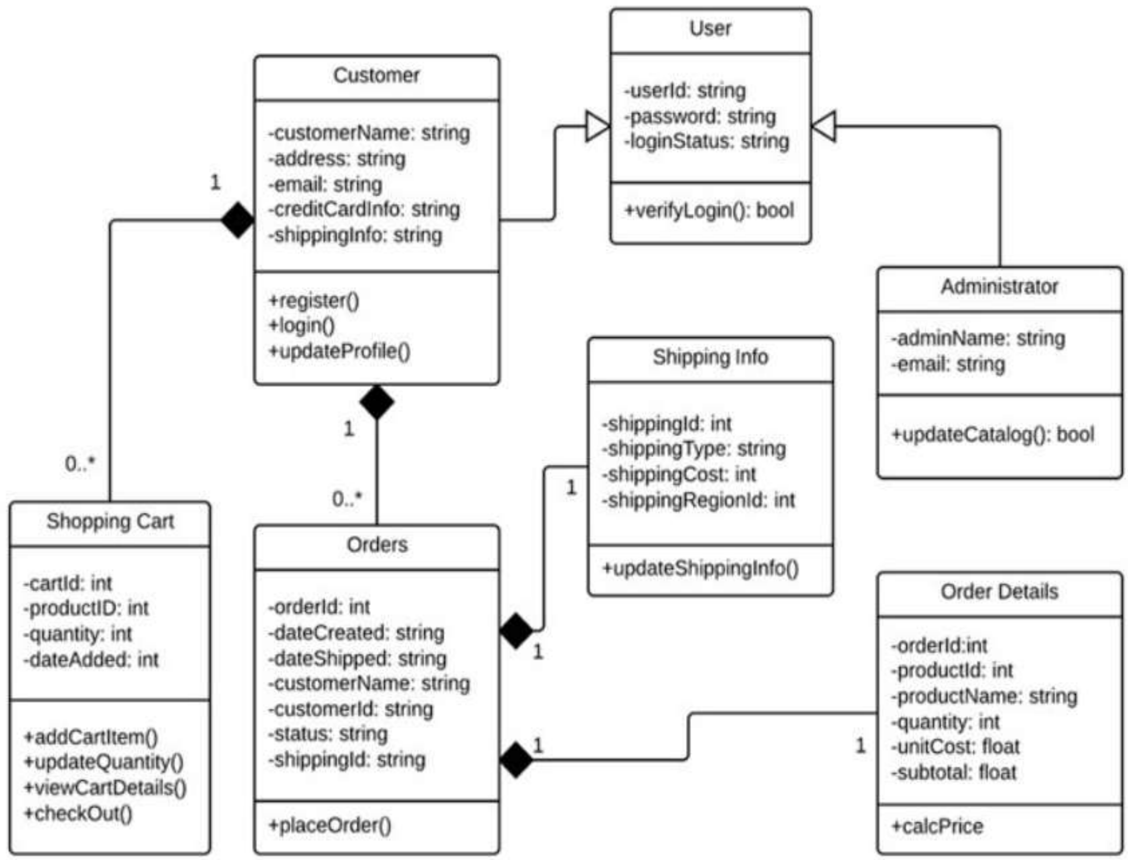
2.5.2) Activity Diagram



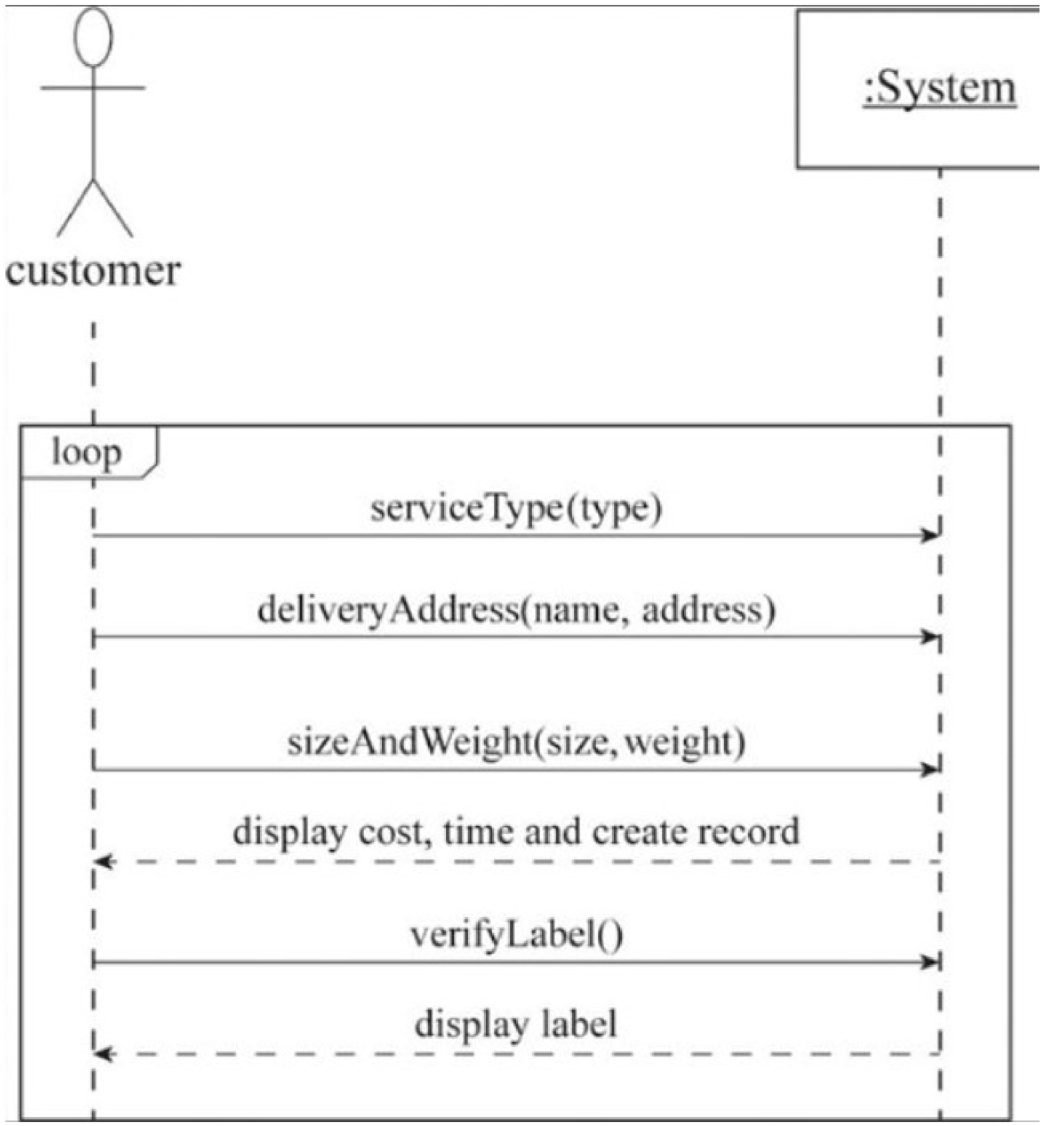
2.5.3) E-R Diagram



2.5.4) Class Diagram



2.5.5) Sequence Diagram

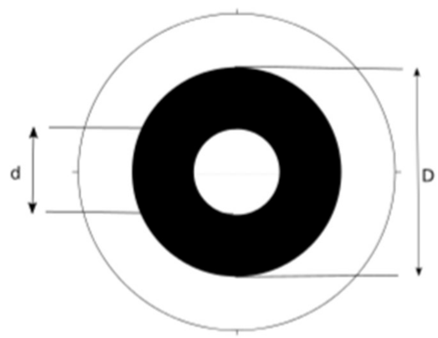


3) Implementation

3.1) Modules in the System

1. **Localization system (WhyCon):**
WhyCon is a vision-based localization system that can be used with low cost web cameras. It achieves millimeter precision with very high performance. These markers consist of a dark outer ring and a concentric white circle.

WhyCon is an open source program that can be either compiled as ROS or a standalone module. Its development was a joint effort between multiple research scholars from multiple universities.
This original system was developed by: Matias Nitsche (Universidad de Buenos Aires)
Tomáš Krajník (Czech Technical University in Prague)
Petr Čížek (Czech Technical University in Prague)
Marta Mejail (Universidad de Buenos Aires)
Tom Duckett (University of Lincoln)
Since then the system has been forked multiple times and many custom suited implementations of it exist currently.
Our project is a fork the program that can be found at: https://github.com/lrse/whycon



WhyCon detection Process:

1. When a camera starts capturing frames, the algorithm starts scanning each frame pixel by pixel. Let us start from a pixel p0. The algorithm checks the first pixel to see if the pixel is white or black using a threshold. On detection of a white pixel it jumps to the next pixel and repeats the process.
2. On finding a black pixel the algorithm employs a queue-based flood-fill technique to detect
contiguous segment of dark circle.
3. The contiguous segment is then tested for possible match for the pattern of the outer ring. The detection of the outer ring is validated by taking minimum number of pixels in the segment and roundness tolerance limit as input from the user.
4. If the segment is found to be invalid (not part of the Outer ring), it is assigned with a unique
identifier so as to avoid redundant computation. The detection for further black segment (to

detect the outer ring) continues starting from the next pixel position.
5. If a black segment is found to be valid (part of the Outer ring), the detection resumes from the
centroid pixel of the black segment to find another continuous area of white or bright pixels
(segment of the Inner ring). Flood fill algorithm is performed again to find a concentric white or
bright circle.
6. If the minimum size and roundness test are passed, further validation is carried out by testing
the centroid position, ratio of the area of black and white pattern according to the user parameters, and complex circularity measures like max-eccentricity parameters etc.
7. If the segment passes all tests, the WhyCon marker is considered as found and the centroid
pixel is considered as p0 for the next detection.
8. Multiple WhyCon markers are detected by running the detector several times consecutively
depending upon the number of targets set by the user.
9. In each iteration, the color of the inner circle pixels is changed to black to prevent multiple
detection of the same target.

WhyCon Localization:

1. Considering the detected pattern as ellipse, the center and semi axes are calculated from the
covariance matrix eigen-vectors and transformed to a canonical camera coordinate system.
2. Canonical form refers to a pin-hole camera model with unit focal lengths and no radial
distortions.
3. The transformed parameters are then used to establish coefficients of the ellipse characteristic equation. These coefficients are subsequently utilized to calculate the patterns' spatial orientation and their positions within the camera coordinate frame.

2) DJI Tello drone controller python package:

This is a python package which controls DJI drone 'Tello'.
This package defines functions that can be used to communicate with the drone. There are many functions defined for multiple controls. These functions take values from the user, converts them to the drone's byte code and sends control packages to the drone.
The official control command API can be found at:
https://tellopilots.com/wiki/protocol/#MessageIDs

3) PID controlled command program (engine.py):

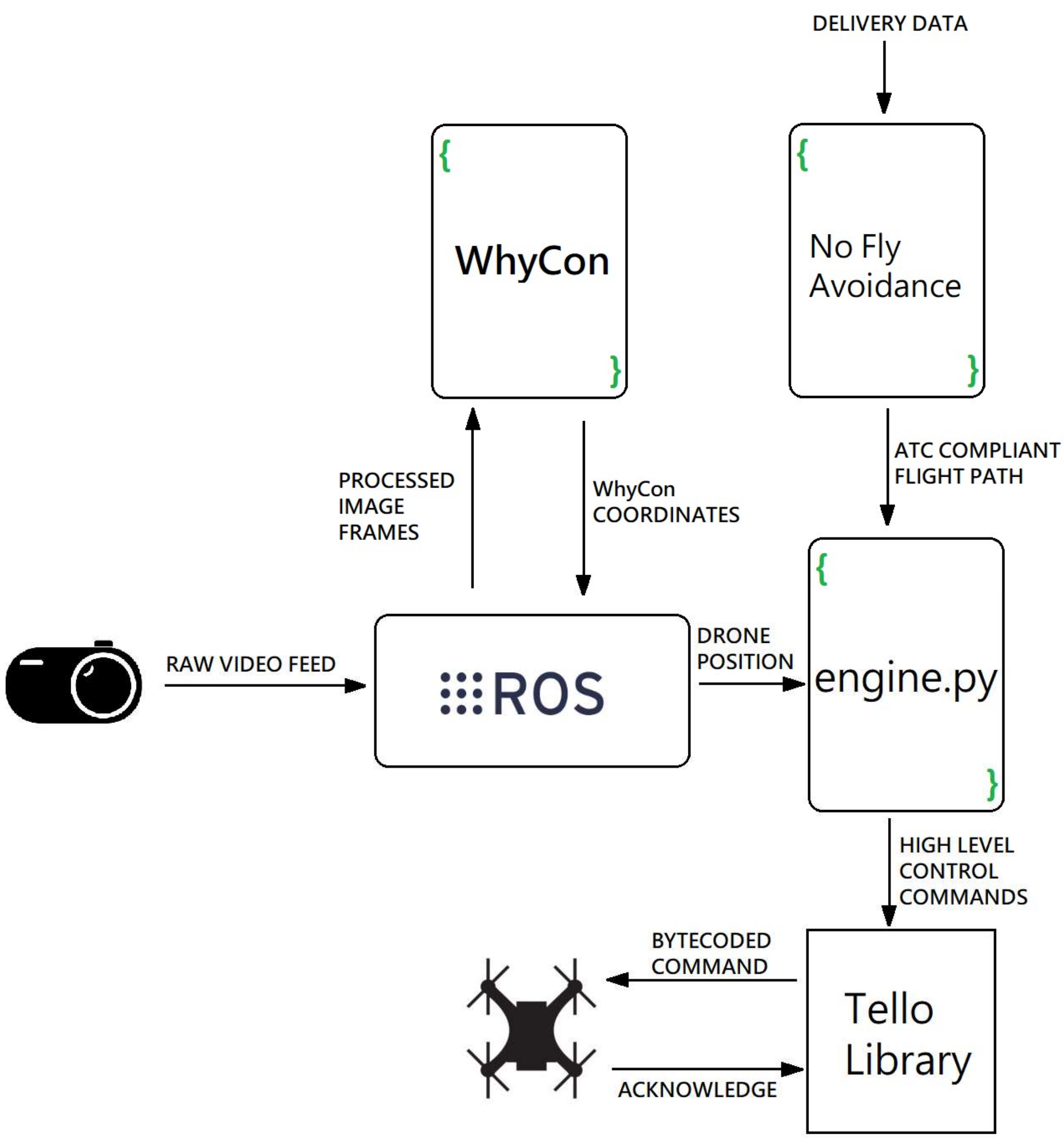
The main program that uses the library functions to command the drone. This program uses a closed feedback loop to control the power commands to the drone and move it to specified waypoints. It gets the location of the drone in from the WhyCon program and gives control commands according to a PID algorithm.

4) **Robot Operating System (ROS):**
The Robot Operating System is a flexible framework for writing robot software. It is a collection of tools and libraries that simplifies the task of creating complex and robust robot behavior across a wide variety of robotic platform.
ROS by itself offers a lot of value to most robotics projects, but it also presents an opportunity to
network and collaborate with the world class roboticists that are part of the ROS community. Over the past several years, ROS has grown to include a large community of users worldwide. ROS being an open source project, the code within it is the result of the combined efforts of this international community.
We have used ROS as the framework to connect and synchronize all our modules. The distribution we have used for our project is ROS-Kinetic.
5) **No fly zone mitigation:**
There are many restricted airspaces within a city. This module has been built from scratch to make our system comply with ATC and other authorities.
This C++ program is in a way a preprocessor to the engine module. It will check the path that a drone has been ordered to take and make sure that it doesn't enter restricted airspaces and hazardous areas designated by the authorities.
The program will plot the entire path of the drone and correct the ones that violate the restrictions.

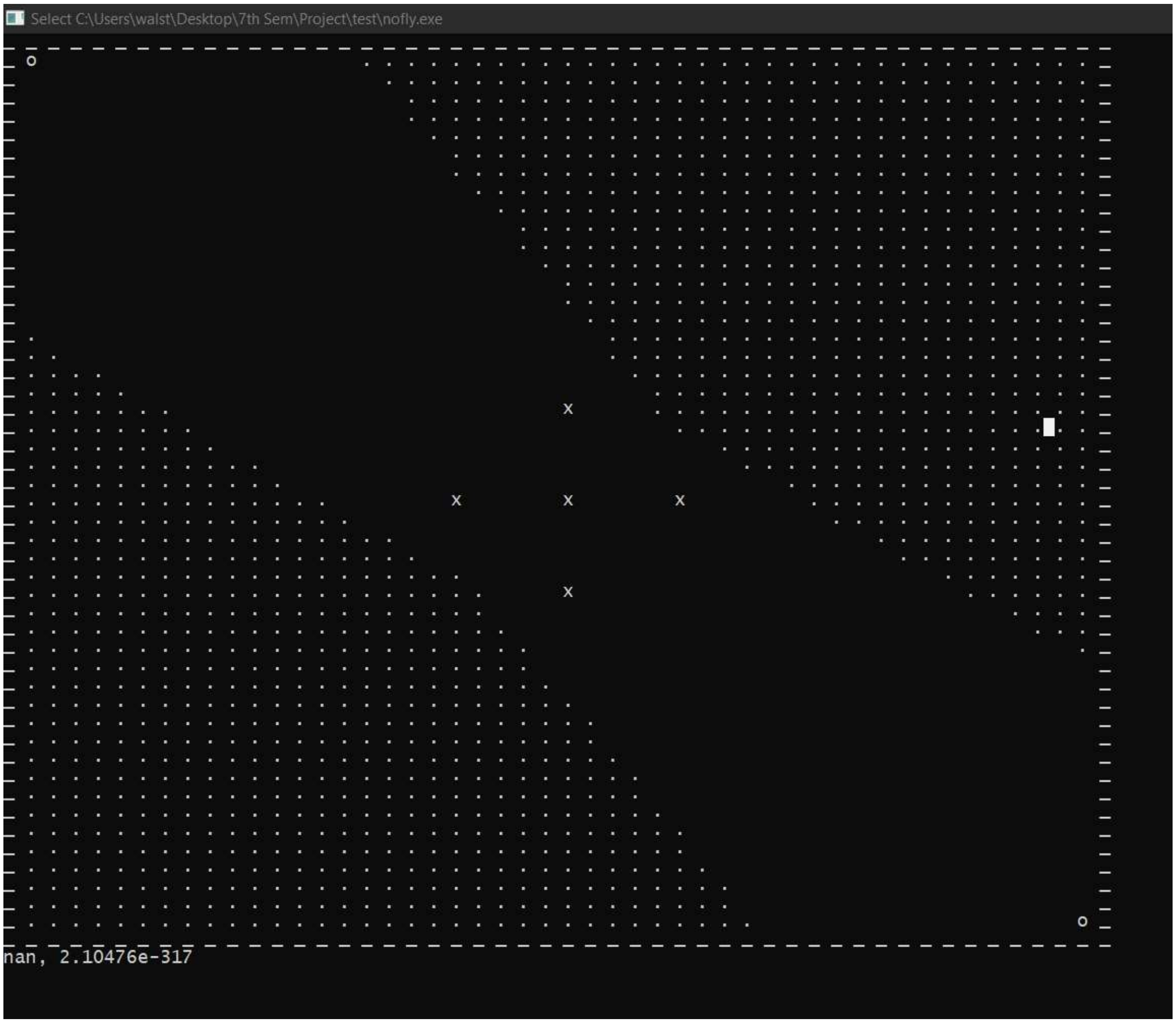
3.2) Data Dictionary

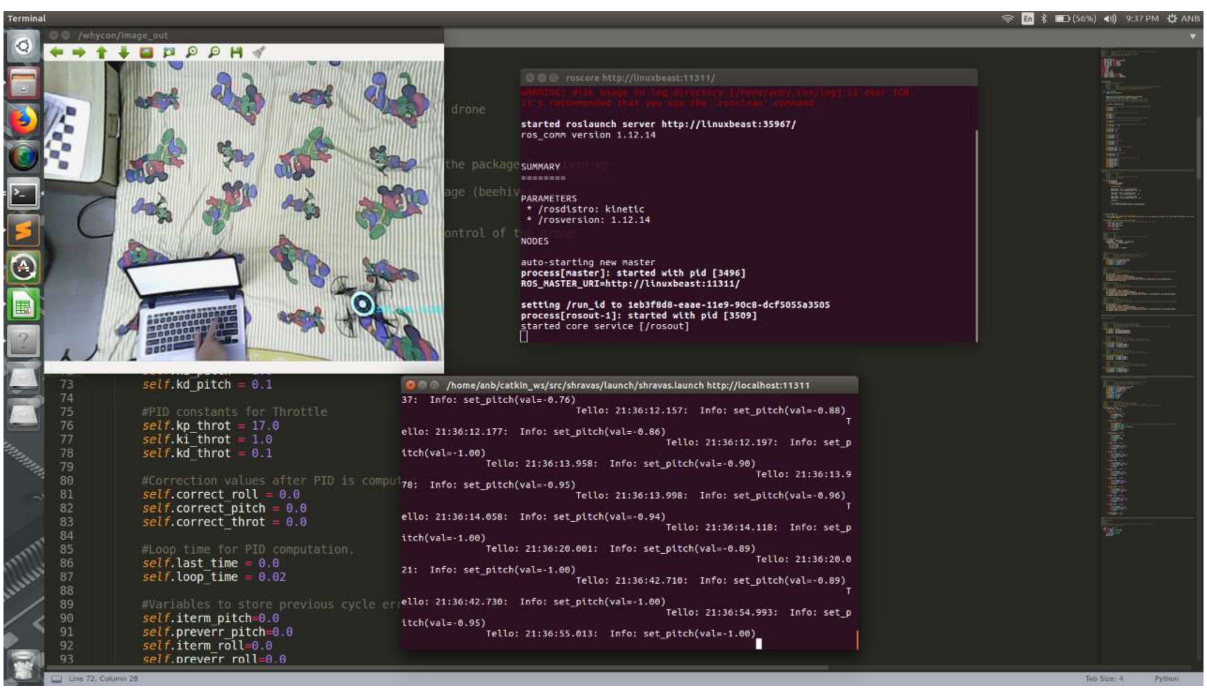
Data	**Description**	**Type**	**Skippable**
wp_x	An array to store the x-coordinate of the delivery locations.	float[]	No
wp_y	An array to store the y-coordinate of the delivery locations.	float[]	No
wp_z	An array to store the z-coordinate of the delivery locations.	float[]	No
wp_package	An array to store the package to be delivered at the corresponding drop location specified by the wp arrays.	float[]	Yes
Drone_x	Variable to store the current x coordinate of the drone	float	No
Drone_y	Variable to store the current y coordinate of the drone	float	No
Drone_z	Variable to store the current z coordinate of the drone	float	No

3.3) Flow


DELIVERY DATA
WhyCon
No Fly
Avoidance
PROCESSED
IMAGE
FRAMES
WhyCon
COORDINATES
ATC COMPLIANT
FLIGHT PATH
RAW VIDEO FEED
ROS
DRONE
POSITION
engine.py
HIGH LEVEL
CONTROL
COMMANDS
BYTECODED
COMMAND
Tello
Library
ACKNOWLEDGE

3.4) Screenshots




Terminal
/whycon/image_out
drone
the package
age (beehiv
ontrol of t
roscore http://linuxbeast:11311/
started roslaunch server http://linuxbeast:35967/
ros_comm version 1.12.14
SUMMARY
========
PARAMETERS
* /rosdistro: kinetic
* /rosversion: 1.12.14
NODES
auto-starting new master
process[master]: started with pid [3496]
ROS_MASTER_URI=http://linuxbeast:11311/
setting /run_id to 1eb3f8d8-eaae-11e9-90c8-dcf5055a3505
process[rosout-1]: started with pid [3509]
started core service [/rosout]
73 self.kd_pitch = 0.1
74
75 #PID constants for Throttle
76 self.kp_throt = 17.0
77 self.ki_throt = 1.0
78 self.kd_throt = 0.1
79
80 #Correction values after PID is comput
81 self.correct_roll = 0.0
82 self.correct_pitch = 0.0
83 self.correct_throt = 0.0
84
85 #Loop time for PID computation.
86 self.last_time = 0.0
87 self.loop_time = 0.02
88
89 #Variables to store previous cycle err
90 self.iterm_pitch=0.0
91 self.preverr_pitch=0.0
92 self.iterm_roll=0.0
93 self.preverr_roll=0.0
/home/anb/catkin_ws/src/shravas/launch/shravas.launch http://localhost:11311
37: Info: set_pitch(val=-0.76)
Tello: 21:36:12.157: Info: set_pitch(val=-0.88)
T
ello: 21:36:12.177: Info: set_pitch(val=-0.86)
Tello: 21:36:12.197: Info: set_p
itch(val=-1.00)
Tello: 21:36:13.958: Info: set_pitch(val=-0.90)
Tello: 21:36:13.9
78: Info: set_pitch(val=-0.95)
Tello: 21:36:13.998: Info: set_pitch(val=-0.96)
T
ello: 21:36:14.058: Info: set_pitch(val=-0.94)
Tello: 21:36:14.118: Info: set_p
itch(val=-1.00)
Tello: 21:36:20.001: Info: set_pitch(val=-0.89)
Tello: 21:36:20.0
21: Info: set_pitch(val=-1.00)
Tello: 21:36:42.710: Info: set_pitch(val=-0.89)
T
ello: 21:36:42.730: Info: set_pitch(val=-1.00)
Tello: 21:36:54.993: Info: set_p
itch(val=-0.95)
Tello: 21:36:55.013: Info: set_pitch(val=-1.00)
Line 72, Column 28
Tab Size: 4
Python

4) Summary

4.1) Advantages of the System

- The current conventional logistics system for delivery requires much involvement of an individual where the task at hand is very basic and can easily accomplished with little to no human resource.
- The current conventional system exhausts human resources and various other dependent resources without there being any need to and could be instead replaced with an automated approach.
- Our approach to the problem would reduce the need of a person's involvement, and also provide quicker and more efficient delivery of packages.
- QuadDrop is the most cost-effective, quick, efficient and least strenuous logistics system.
- This system would provide a most economic path of delivery for the drone while keeping in mind various constraints such as flight path, flight duration, distance, customer priority, restricted fly zones, Drone Flight regulations etc.
- QuadDrop would provide door to door delivery and significantly reduce last-mile delivery costs and also reduce delivery times, which is currently considered as challenging task for conventional delivery systems.
- As conventional last-mile delivery solutions provide package delivery by taking a bulk shipment of packages for delivery, there are chances that some packages would get damaged while transit, our system would simply eliminate the chance of a package getting damaged during transit since it would not be carrying bulk packages and also, it would not be by road.

4.2) Unique Features

- Mostly automated and little to no human involvement.
- Economic and Cost-efficient.
- Direct door to door delivery.
- Environment-friendly and energy-efficient.
- Quick and faster delivery times.
- Continuously tracked and monitored.
- Based on a real-time navigation system.
- Less tedious and strenuous process.
- Can access physically unreachable areas.
- Can take paths which otherwise would not be efficient by road.
- Safety features such as to immediately cancel flight and land wherever it is and for manual takeover of drone at any given point of time.
- Security features such as to take pictures and video feed from the onboard camera.
- System designed considering UAV flight regulations.

4.3) Conclusion and Scope of further Work

- QuadDrop currently in development already has basic functionality as to perform Drone deliveries on a prototype Tello drone for multiple delivery points.
- The selected prototype drone Tello is adequate for the demonstration of our system.
- It is a very capable drone with a 14 core Intel Atom processor and a flight range of up to 50 meters. A Waypoint route system calculates an alternative waypoint to reach a particular destination in case of an obstructing flight restricted area.
- Currently, our system takes into consideration constraints such as distance, restricted flight zone, time of flight and optimizes the flight path accordingly.
- The current prototype functions on WhyCon-based navigation system, where an overhead camera provides the real-time coordinates of the location of the drone by image tracking of a WhyCon pointer.
- The overhead camera is wired low latency camera which is mounted above the flight zone which covers the complete flight area and thus providing live video feed input to the WhyCon-based navigation system.
- Thus, providing the system with a continuous tracking and monitoring of the drone.
- Control and communication with the drone can be done with the help of ROS commands sent and received over Wi-fi.
- The PID controller provides major control, stability and navigation functionality to the drone. The PID controller is specifically tuned to achieve quick efficient and maximum stability to our particular prototype drone Tello.
- We were able to achieve flight from start to the delivery locations, avoiding the restricted flight zones in our initial test flights.
- We have also implemented various safety features, such as to immediately cancel flight and land wherever it is and for manual takeover of drone at any given point of time and security features such as to take pictures and video feed from the onboard camera. We have also kept in mind various UAV flight regulations and designed the system accordingly.
- We plan to develop a fully functioning, user-friendly, intuitive and interactive User Interface to assign delivery locations and manage the delivery of packages.
- We further aim to develop a system that also takes into consideration constraints such as package weight, customer priority, battery capacity, real-time flight path alterations, wind speed and weather.
- We would like to add various safety and security features such a collision avoidance and self-piloting, facial recognition, package security, etc.
- We would also like to further improve this project by removing major limitations such as drone capacity, navigation systems, flight limitations etc., which would require a majority of financial support and research & development for specifically designing an aerial autonomous drone that would check all the boxes needed for the system to function at its maximum.

This system at its peak could prove to be a revolutionary logistics system.

5) References

- https://github.com/hanyazou/TelloPy
- https://www.dronezon.com/learn-about-drones-quadcopters/best-educational-drones-kits-to-build-and-code-uavs/
- https://tellopilots.com/
- https://tellopilots.com/wiki/protocol/
- https://docs.python.org/3/
- https://github.com/lrse/whycon
- https://www.ros.org/
- https://terra-1-g.djicdn.com/2d4dce68897a46b19fc717f3576b7c6a/Tello%20%E7%BC%96%E7%A8%8B%E7%9B%B8%E5%85%B3/For%20Tello/Tello%20SDK%20Documentation%20EN_1.3_1122.pdf
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- https://www.geeksforgeeks.org/check-line-touches-intersects-circle/
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