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Project Proposal

(SCOPE DOCUMENT)

for

AUTONOMOUS QUADCOPTER

Version 2.0

By

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SCOPE DOCUMENT REVSION HISTORY

No.	Comment	Action

Supervisor Signature

Date:

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Project Category:

○ **A -** Desktop Application/Information System	○ **C -** Problem Solving and Artificial Intelligence

Abstract

The Project that is being developed is called "Autonomous Quadcopter". A quadcopter will be built with NVIDIA Jetson TX2, which is the most power-efficient embedded AI computing device, onboard for executing computationally intensive and time sensitive Computer Vision, Navigational and Control Algorithms in real-time. These algorithms will help the quadcopter to fly autonomously and complete missions while making all decisions itself. With the help of these algorithms the quadcopter will be able to detect any potential obstacles in its path and avoid them when necessary, autonomously follow an object being tracked, autonomously navigate from a starting position to destination, autonomously navigate over an area while automatically capturing images for generating 2D maps. The user will use Mission Ground Control Application to control and assign any mission to the quadcopter.

1. Introduction

The purpose of this project proposal document is to briefly describe the system being developed. This document includes the project's working, capabilities, features, limitations and constraints. The advantages provided by our system will be listed along with the viable solutions it offers regarding existing problems to prove why our project might be best and unique compared to existing applications. The tools and technologies which will be implemented and integrated during the lifetime of our project will also be included. The concepts which shall be learned and implemented during the Software Development Life Cycle have been included to depict the domains that our project encompasses.

2. Problem Statement

Quadcopter have been around for decades now and most of them are still being controlled from radio transmitters and some are being controlled from smartphones. There have been tremendous amounts of incremental and iterative improvements throughout the years but still quadcopters must be controlled by humans. Therefore, it can be assumed that the limit to a quadcopter's ability depends upon the skillfulness of its pilot. Consumer grade quadcopters don't have enough computational power onboard to execute computationally intensive and time sensitive Computer Vision algorithms. Researchers, enthusiasts and hobbyist usually send live camera feed and sensor data to external computers for computation and decision making. Computed decisions are then sent to the drone for execution. This process introduces a seemingly small but significant delay between consecutive actions performed by the drone and this simultaneously introduces a high degree of risk of failure and collision.

3. Problem Solution for Proposed System

To solve this problem, we must take the human factor out of the equation. We propose a system that will make a quadcopter aware of its surroundings by using extremely powerful and cutting-edge Computer Vision techniques such as Visual Simultaneous Localization and Mapping (Visual SLAM) and Visual Inertial Odometry (VIO). These techniques will not only enable the quadcopter to fly autonomously but also enable it to make logical decisions depending upon its environment. NVIDIA Jetson TX2, which is a power efficient yet high performance embedded system, placed onboard the quadcopter is being used for the executions of these performance demanding Computer Vision algorithms. Due to this, the performance will be in real-time without encountering any delay which will help in reducing risk caused by time delays.

4. Related System Analysis

The system related to the proposed system comprises of Quadcopters from Consumer and Professional Drones Manufacturers like **DJI, Parrot**, **Syma**, **JJRC** etc**.** Most of their drones must still be controlled from Radio Transmitter or smartphone. Some of their products are regarded as intelligent and smart by their respective companies yet they still don't have any form of Obstacle Detection and Obstacle Avoidance. Names of some popular and expensive products from **Parrot**, **DJI** and **Syma**, their weakness and proposed solution are mentioned in the following table.

Table 1 - Related System Analysis with proposed project solution

Product Name	Weakness	Proposed Project Solution
Drones from Parrot like Parrot Bebop 2, Parrot Mambo and Parrot Anafi etc.	• Must be controlled by human pilot. • No obstacle detection and obstacle avoidance technique used in any quadcopters. • Object Tracking technique uses target’s smartphone’s GPS sensor to locate the target. • No powerful hardware for onboard computation and decision making.	• Fully Autonomous Flight without any external existence. • Intelligent Obstacle Detection and Obstacle Avoidance Techniques. • Effective and Robust Visual Tracking System. • Contains Powerful embedded system for real-time processing and decision making.
Drones from DJI like the Mavic Air and Mavic Pro, Spark, Phantom 3 and Phantom 4 etc.	• Must be controlled by human pilot. • Average Object Tracking technique used in some quadcopters. • No powerful hardware for onboard computation and decision making.	• Fully Autonomous Flight without any external existence. • Effective and Robust Visual Tracking System. • Contains Powerful embedded system for real-time processing and decision making.
Drones from Syma like X25 Pro, X8 Pro, X23W, X22W, X5UW-D etc.	• Must be controlled by human pilot. • No obstacle detection and obstacle avoidance techniques used in all quadcopters. • Object Tracking technique uses target’s smartphone’s GPS sensor to locate the target. • No powerful hardware for onboard computation and decision making.	• Fully Autonomous Flight without any external existence. • Intelligent Obstacle Detection and Obstacle Avoidance Techniques. • Effective and Robust Visual Tracking System. • Contains Powerful embedded system for real-time processing and decision making.

5. Advantages/Benefits of Proposed System

Advantages of the proposed system are as follows:

- Tracking and Surveillance
- Way point Navigation
- Mapping
- Unmanned Delivery System
- Aerial Photography
- Warehouse and Infrastructure Inspection
- Search and Rescue
- Construction
- Crop Spraying
- Wildlife, Forrest Fire and Crops Monitoring

6. Scope

The proposed system comprises a set of Computer Vision, Navigation and Controlling based programs necessary for making an autonomous quadcopter. All processing, execution and decision will be made using onboard embedded system namely NVIDIA Jetson TX2. This will enable the quadcopter to process all data onboard and make decisions asynchronously without encountering any delays.

The user will use Mission Ground Control Application to assign any mission to the quadcopter. The user must select a mission from the Mission Menu and then complete the mission requirements to assign the mission to the quadcopter. Mission requirements will vary from mission to mission. For tracking based mission, the user must select a target from live video feed to be tracked and follow by the quadcopter. For waypoints navigation based mission, the user must select waypoint by clicking on Google Earth Map at different locations. The user could also specify in which order the waypoints should be traversed and the height to maintained throughout the flight. For mapping missions, the user must select an area from the Google Earth that is to be mapped and the height to be maintained while mapping.

The quadcopter will be able to track an object (specified by user) and autonomously follow it. The quadcopter will be able to autonomously navigate from a starting position to destination (specified by user). The quadcopter will be able to autonomously navigate over an area (specified by the user) according to a generated flight path while automatically capturing images that will then be used to generate a Google Earth like 2D map. The quadcopter will perform all these tasks while detecting any potential obstacles in its flight path and avoiding them when necessary without any external assistance.

7. Modules

Following are the major modules that the proposed system shall be comprised of:

7.1 Building the Quadcopter:

This module comprises of building up the quadcopter. A custom quadcopter must be built so that it can accommodate the NVIDIA Jetson TX2 within its frame and be able to fly firmly and steadily under its weight.

7.2 Flight Testing the Quadcopter:

This module comprises of a series of flight tests that are performed upon the quadcopter in real-time to ensure that it can perform certain flight modes like Altitude Hold Mode, Loiter Mode and Stabilized Mode which are coded into it. If the quadcopter can perform the above coded modes, then it can be assumed that the quadcopter is aerodynamically stable.

7.3 Collision Detection:

This module comprises of testing Computer Vision techniques like Visual SLAM and Stereo Depth Mapping to determine obstacles that are potential candidates for collision.

7.4 Collision Avoidance:

This module comprises of testing navigation and control algorithms necessary to avoid obstacles that are potentially capable of collision soon. These algorithms will not only guarantee avoidance from collisions but also maintain stabilized flight during the evasion process.

7.5 Tracking and Navigation:

This module comprises of tracking and navigation algorithms. The tracking algorithms will enable the quadcopter to track specific objects, specified by the user, in the live video feed. The navigation algorithms will control the trajectory, speed and angles of the quadcopter to constantly follow the tracked subject. The quadcopter will follow the tracked subject while constantly detecting and avoiding any potential obstacles.

7.6 Waypoints Navigation:

This module comprises of a task of navigating the quadcopter from initial point to final point. These points are set using GPS coordinates from maps like Google Earth or Google Maps. The user will be able to select any number of GPS coordinates for the quadcopter for the quadcopter to navigate to or from. The quadcopter will navigate to or from all specified GPS coordinates while constantly detecting and avoiding any potential obstacles.

7.7 2D Mapping:

This module comprises of task of mapping an area by taking multiple pictures of the area and stitching them up together to form a Google Earth like map. The user will be able to select the area to be mapped, then the program will generate a flight path and points at which images will be captured that will tend to cover the entire area to be mapped. The quadcopter will automatically takeoff and travel to the starting point. After reaching the starting position the quadcopter will start travelling on the generated flight path while automatically capturing images at generated capture points. After the quadcopter has completed its flight path it will return to the takeoff position and land automatically. The captured images will then be stitched together to form a Google Earth like map.

7.8 Mission Ground Control:

This module comprises of a fully featured ground station application for controlling and assigning tasks to the quadcopter. With Mission Ground Control, flight information can be converted for use in Google Earth. Mission Ground Control gives you the ability to view your flight path over the terrain map in Google Earth. Tracking and Waypoint Navigation tasks will be assigned using the Mission Ground Control. The drone can also be programmed to take off and land autonomously and fly using different flight modes using the Mission Ground Control. The user can also program other flight parameters such as speed and altitude of the drone over each waypoint. The Mission specifications will be sent to the drone via telemetry connection.

7.9 Emergency Handling:

This module comprises of a set of strategies for handling emergencies. These strategies include:

- Knowing how much battery could be consumed while starting a waypoint navigation to determine whether the drone could successfully complete its mission provided a certain amount of charged battery.
- If a drone is unable to complete a waypoint navigation mission due to a windstorm or loss of GPS connection or low battery because of trying to fly to a point in a windstorm, it should check if it has enough battery to return home or find a suitable place to land and send GPS location of its landing spot so that it can be located by the user.

8. System Limitations/Constraints

Limitations and constraints of the proposed system are as follows:

- Quadcopter is not water resistant therefore it must not be deployed in rain.
- Quadcopter cannot fly in low light or at night.
- During testing the Quadcopter should not be deployed in crowded areas as it proposes a high degree of risk.

9. Software Process Methodology

The selected software development methodology is Incremental method because of its nature to decompose the required product into several components depending upon functionality, each of which is designed and built separately. The incremental software development method is a method of software development where the product is designed, implemented and tested incrementally. Project requirements are divided into separate modules and each of them are developed separately. It is beneficiary to use Incremental model in developing large applications as it allows to complete each functionality of the required product incrementally and to add additional functionality later.

10. Tools and Technologies

Following hardware, software tools, technologies and libraries will be used for the development of the proposed system:

Table 2 - Hardware Required for Proposed Project

Hardware	Quantity
NVIDIA Jetson TX2	1
F450 Quadcopter Frame	1
Brushless Motors	4
Electronic Speed Controllers	4
Propellers	4
Global Positioning System	1
Telemetry	1
Power Distribution Board	1
Camera	9
Ultrasound Range Sensor	2
Battery	2
Battery Charger	1
Soldering Iron	1
Jumper Cables	-
Cable Zip Ties	-

Table 3 - Programming Tools required for Proposed Project

Programming Tools	Version	Rationale
PyCharm	2018.2	Python IDE
Unity	2018.2.8	Application Development
MonoDevelop	7.5	C# Code Editor
Notepad++	7.5.8	Code Editor
Balsamiq	3.5.16	Mockups Creation
Microsoft Word	365	Documentation
Microsoft Power Point	365	Presentation

Table 4 - Technologies required for Proposed Project

Technologies	Version	Rationale
Python	3.7	Programming Language
C#	7.3	Programming Language

Table 5 - Libraries required for Proposed Project

Libraries	Version	Rationale
TensorFlow	1.10	Deep Learning Library
OpenCV	3.4.2	Computer Vision Library
OpenDroneMap	0.4	Image Stitching Library
Robot Operating System	12	Robotics Libraries
NVIDIA JetPack SDK	3.3	Jetson Developer Kit

11. Project Stakeholders and Roles

Table 6 - Project Stakeholders for Proposed Project

Project Sponsor	COMSATS University, Islamabad

Stakeholder	• **Students Names:**
	  ○ Mirza Muhammad Bin Adnan Baig
	  ○ Hamza Ahmad
	  ○ Muhammad Ussama Irfan
	• **Project Supervisor Name:** Dr. Tahir Mustafa Madni
	• **Final Year Project Committee:** Evaluation of project

12. Team Members Individual Tasks/Work Division

Table 7 - Team Member Work Division for Proposed Project

Student Name	Student Registration Number	Responsibility / Modules
Mirza Muhammad Bin Adnan Baig	FA15 - BCS - 048	• Building the Quadcopter • Flight Testing the Quadcopter • Emergency Handling
Hamza Ahmad	FA15 - BCS - 069	• Obstacle Detection • Obstacle Avoidance • Tracking and Navigation

Muhammad Ussama Irfan	FA15 - BCS - 088	• Waypoints Navigation • 2D Mapping • Mission Ground Control

13. Data Gathering Approach

Several benchmark Computer Vision datasets will be gathered from the internet for testing Computer Vision algorithms like Visual Simultaneous Localization and Mapping (Visual SLAM), Visual Inertial Odometry, Vision Based Tracking and Navigation before being deployed on to the quadcopter.

14. Concepts

14.1 Quadcopter Dynamics:

The team will learn how quadcopter dynamics work and how it behaves under different circumstances. These concepts will act as the foundation of our project. This will allow us to control the quadcopter more precisely under varying environmental conditions.

14.2 Computer Vision:

The team will learn different techniques and algorithms of Computer Vision that will enable us to implant a certain degree of intelligence in the quadcopter to make it aware of its surrounding so that it can controls itself without needing any external assistance.

14.3 Assembling the Quadcopter:

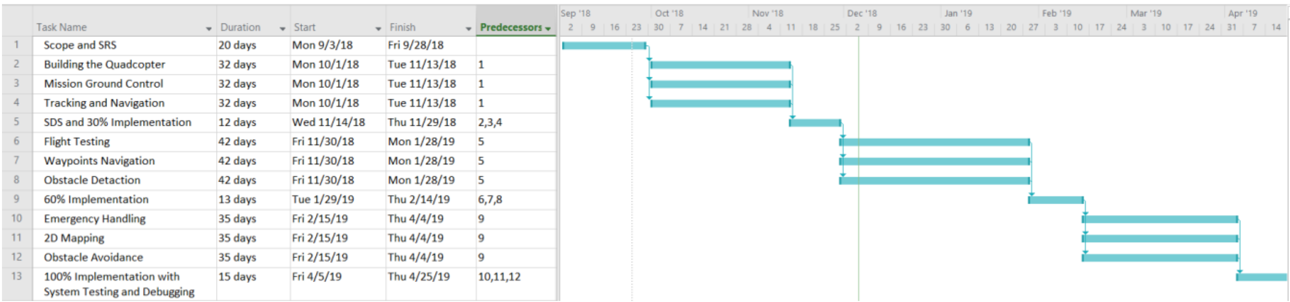
The team will learn how different components of a quadcopter works and how to assemble them correctly to ensure a safe and an aerodynamically stable flight. The team will also learn how to connect the NVIDIA Jetson TX2 to the quadcopter so that it can control the quadcopter onboard.

14.4 Communicating with the Quadcopter:

The Team will learn how to send mission controls to the quadcopter and receive real-time sensors readings from the quadcopter wirelessly. After instructing the quadcopter to perform a certain mission, the real-time sensors readings will help us to monitor the state of the quadcopter during the lifecycle of the mission assigned.

15. Gantt chart

The following Gantt chart shows the estimated time line of the project development phases.



	Task Name	Duration	Start	Finish	Predecessors
1	Scope and SRS	20 days	Mon 9/3/18	Fri 9/28/18	
2	Building the Quadcopter	32 days	Mon 10/1/18	Tue 11/13/18	1
3	Mission Ground Control	32 days	Mon 10/1/18	Tue 11/13/18	1
4	Tracking and Navigation	32 days	Mon 10/1/18	Tue 11/13/18	1
5	SDS and 30% Implementation	12 days	Wed 11/14/18	Thu 11/29/18	2,3,4
6	Flight Testing	42 days	Fri 11/30/18	Mon 1/28/19	5
7	Waypoints Navigation	42 days	Fri 11/30/18	Mon 1/28/19	5
8	Obstacle Detaction	42 days	Fri 11/30/18	Mon 1/28/19	5
9	60% Implementation	13 days	Tue 1/29/19	Thu 2/14/19	6,7,8
10	Emergency Handling	35 days	Fri 2/15/19	Thu 4/4/19	9
11	2D Mapping	35 days	Fri 2/15/19	Thu 4/4/19	9
12	Obstacle Avoidance	35 days	Fri 2/15/19	Thu 4/4/19	9
13	100% Implementation with System Testing and Debugging	15 days	Fri 4/5/19	Thu 4/25/19	10,11,12

Figure 1: Gantt Chart

16. Mockups

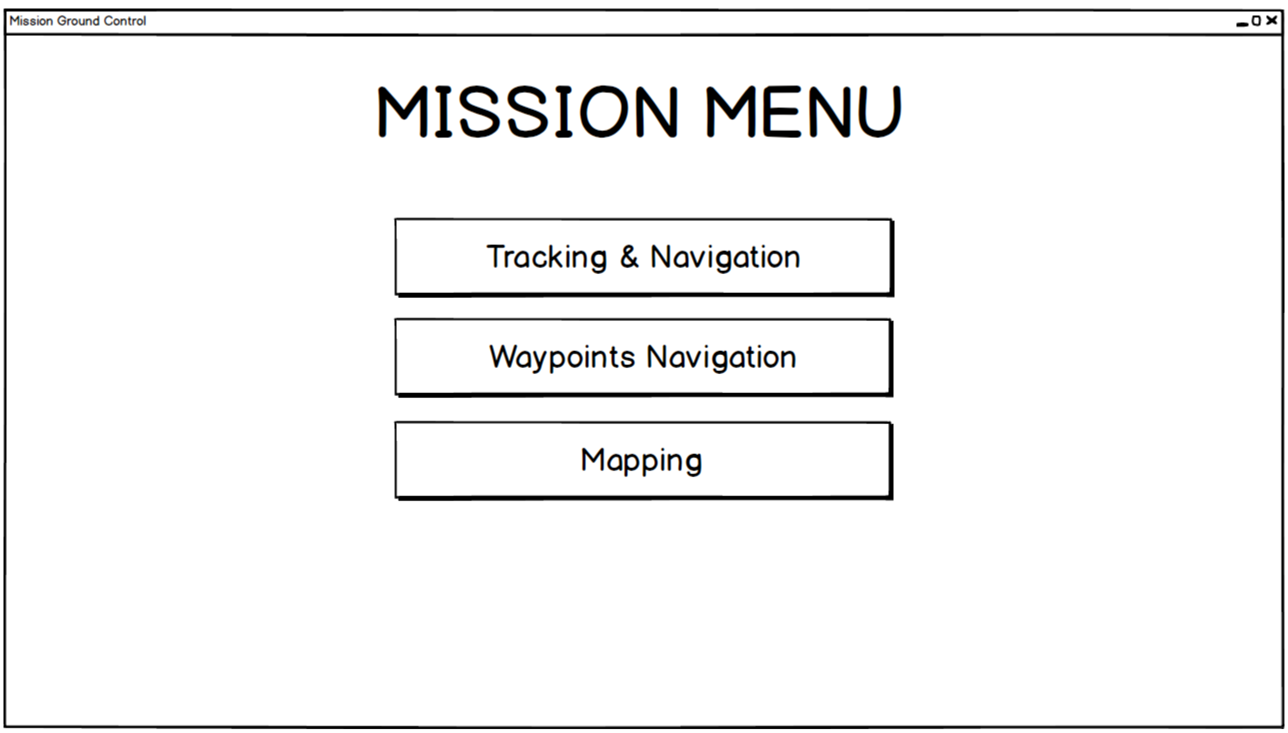


Figure 2: Mission Menu Screen

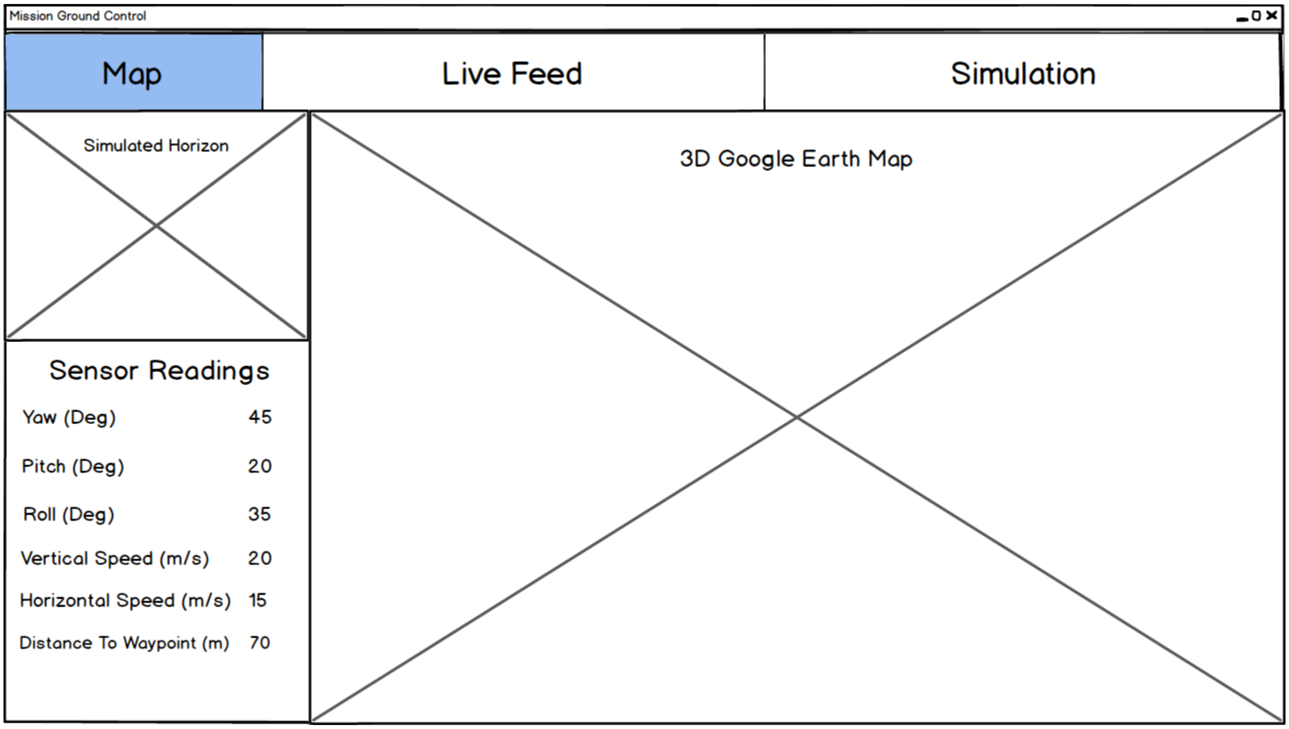


Figure 3: Map Screen

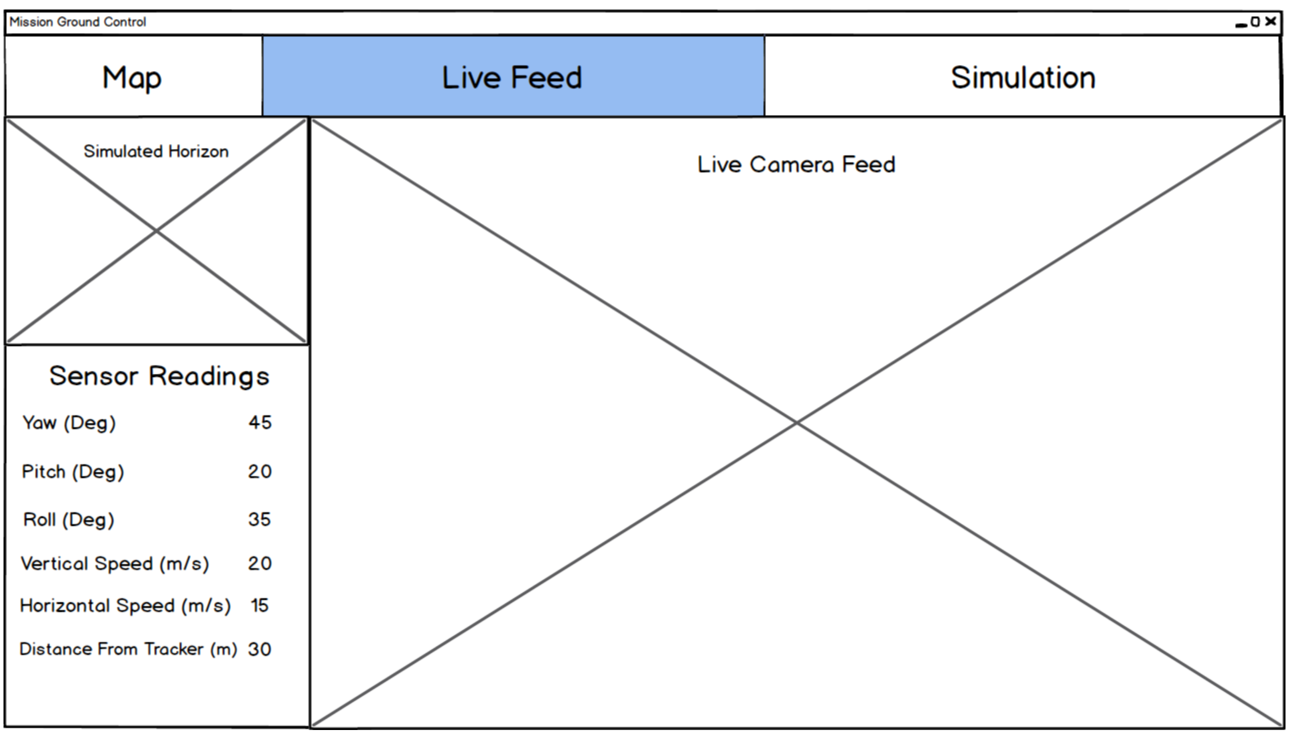


Figure 4: Live Feed Screen

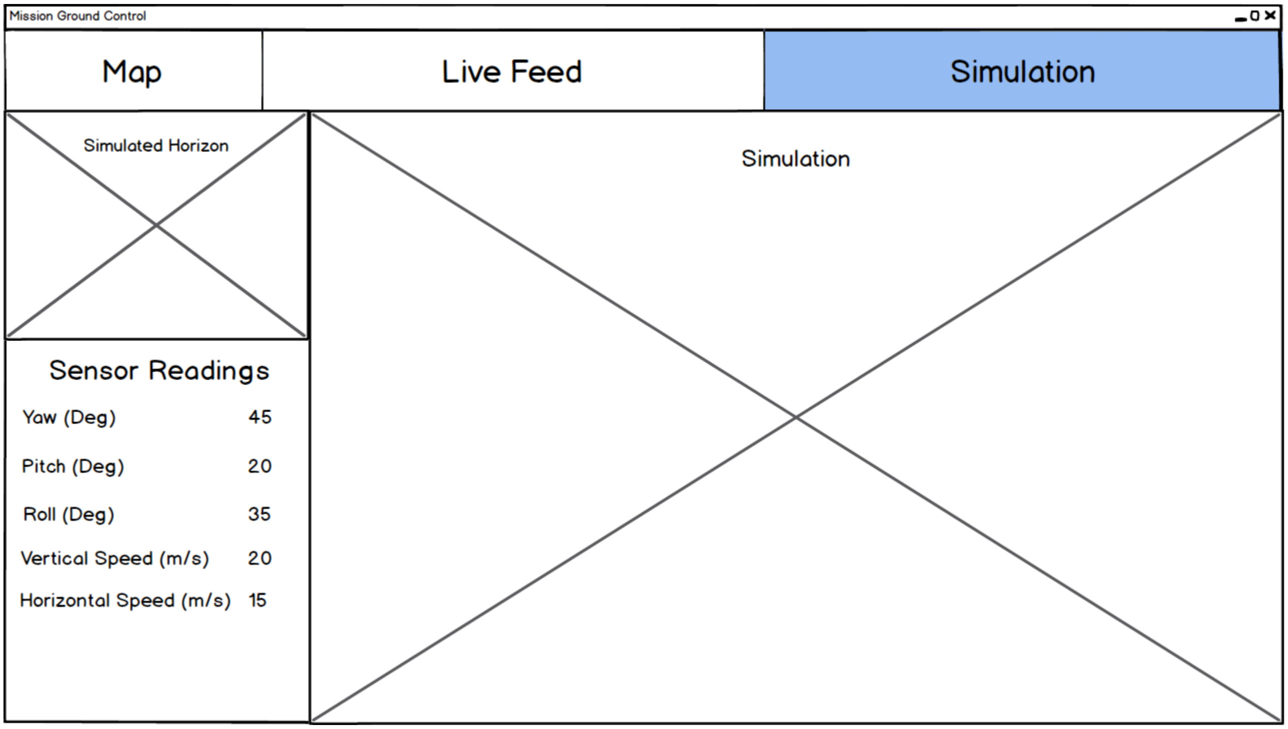


Figure 5: Simulation Screen

17. Conclusion

By developing this system, we will develop a very rich and demanding skill set that will help us in industries, future job opportunities and in developing related products. The system can later be released as a commercial product for public. The primary goal of this project is to achieve high user acceptance and stimulate a high level of excitement by supplying features that existing applications do not provide. As such, we will enter a product which is unmatched in the market and will ultimately outmatch the competition.

18. References

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19. Plagiarism Report

Report

ORIGINALITY REPORT

%10	%1	%1	%9
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Higher Education Commission Pakistan Student Paper	%7
2	Submitted to International Islamic University Malaysia Student Paper	%1
3	Andrew Richardson, Edwin Olson. "PAS: Visual odometry with Perspective Alignment Search", 2014 IEEE/RSJ International Conference on Intelligent Robots and Systems, 2014 Publication	%1
4	Submitted to London School of Science & Technology Student Paper	<%1
5	en.wikipedia.org Internet Source	<%1