Multi-Agent Collaboration for navigation in disaster zone

Team F- Falcon Eye

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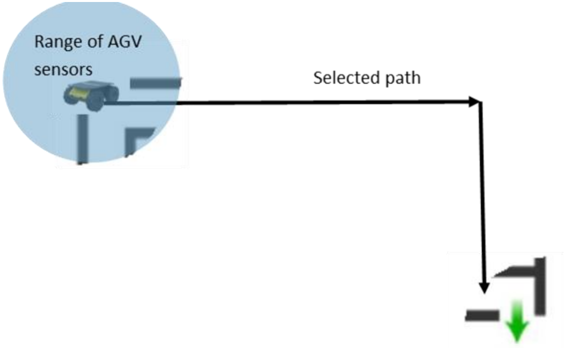
Project description

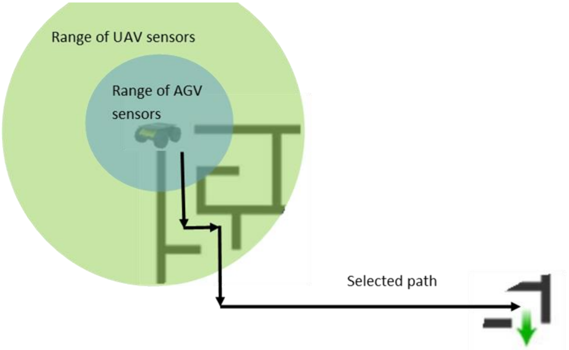
Motivation

Path finding and localization using ground-level sensors is a difficult task when obstacles and dead ends are obstructed from the sensor’s field of view. This can lead to unacceptable performance in time-critical missions in unknown environments - such as disaster relief.

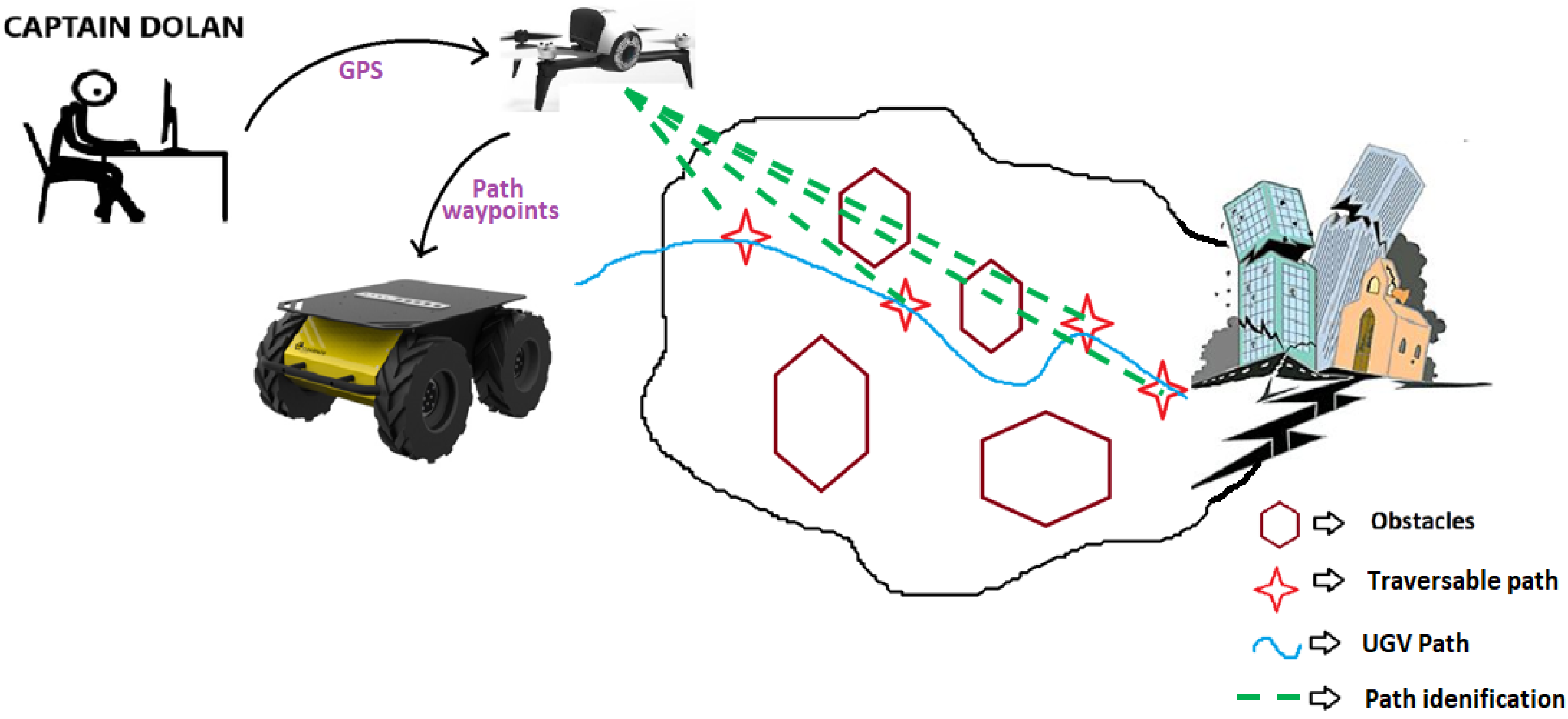


Objective

Our goal is to augment the localization and path planning capabilities of AGV’s by integrating aerial sensor data from UAV’s. This system can be applied to a variety of applications that require autonomous path planning using AGV’s.



Use Case



CAPTAIN DOLAN
GPS
Path
waypoints
Obstacles
Traversable path
UGV Path
Path idenification

Use Case

1. An earthquake has struck in a nearby town. Capt. Dolan is dispatched to provide assistance.
2. He wants to send supplies to the victims and also survey the intensity of damage in the area and to the major roads connecting the town.
3. He sets up the system Falcon Eye team made for him and immediately starts collaborating with other responders, providing them with valuable aerial and ground imagery.
4. Capt. gives input GPS location to the system.

Use Case

5. The UAV takes off and moves to the given location with the AGV.
6. The UAV identifies the best possible traversable path for the AGV to navigate.
7. UAV provides the waypoints to the AGV for its navigation.
8. The AGV navigates in accordance to the given waypoints avoiding obstacles on its way and reaches the disaster zone.
9. The AGV delivers care package to the victims.

System-level requirements
Functional

Functional Requirements		
Mandatory	Fall	The UAV shall recognize fiducial markers
	Fall	The Base computer shall compute distance between fiducial markers
	Fall	The UAV shall autonomously fly to an input GPS location
	Spring	The UAV shall hover around the AGV to guide AGV to the disaster area
	Spring	The AGV shall move to the target location based on inputs from the UAV
	Spring	The AGV shall be able to avoid ground obstacles
Desirable	Spring	The AGV shall combine the data from Lidar, odometry and GPS to generate map of the area
	Spring	The AGV shall be able to localize itself within the area map
	Spring	The AGV shall provide camera feed to the user

- Our requirements have changed significantly since the CoDR after rescoping the project and much discussion with the stakeholders.

System-level requirements Performance

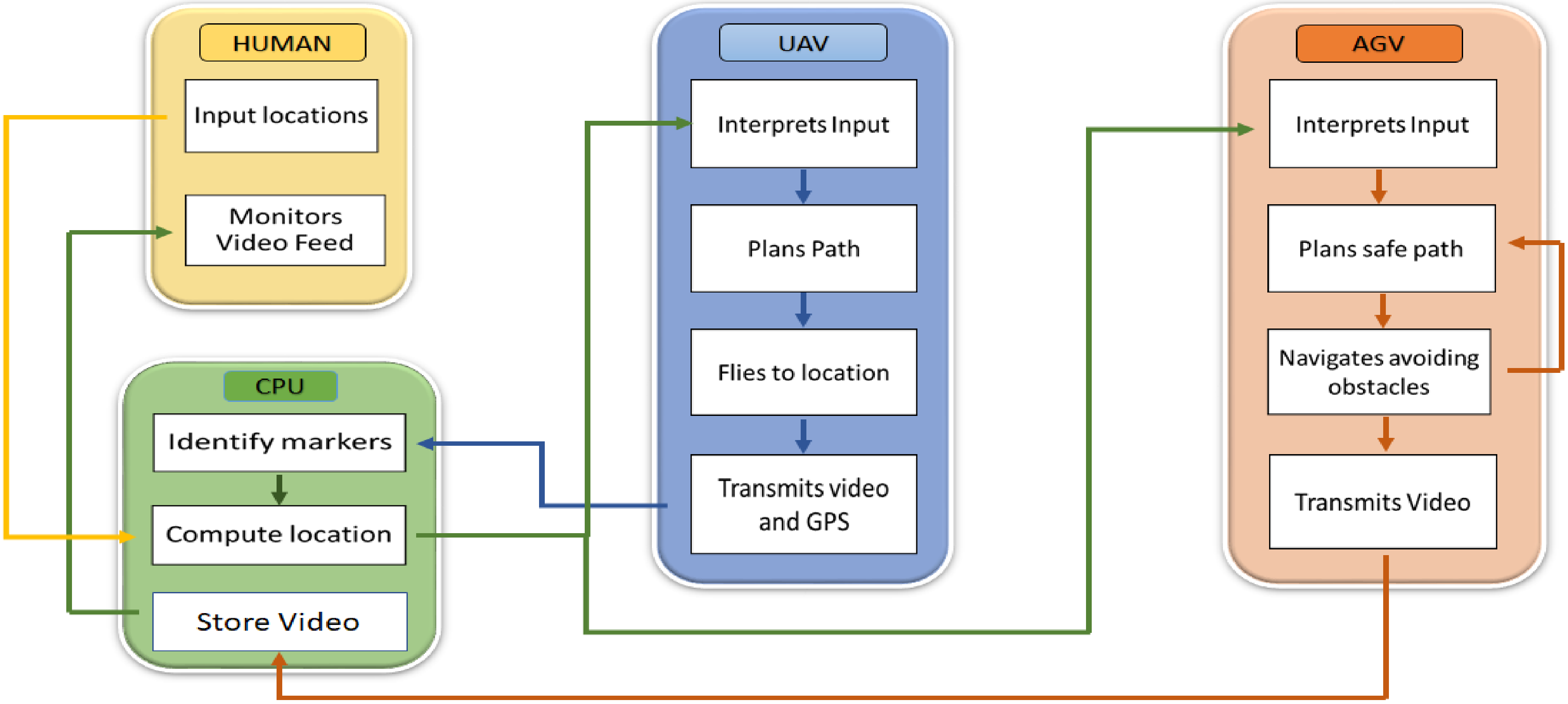
Performance Requirements

Mandatory	Fall	The UAV shall recognize fiducial markers with 80% success.
	Fall	The Base computer shall compute distance between fiducial markers with an accuracy of 30cms
	Fall	The UAV shall autonomously fly to the desired GPS location with 5m accuracy
	Spring	The UAV shall hover around the AGV to guide AGV within 5m radius of the disaster area
	Spring	The AGV shall reach the target location 90% of the times.
	Spring	The AGV shall be able to avoid ground obstacles with 80% accuracy
Desirable	Spring	The AGV shall combine the LiDAR data with Odometry, GPS, and AprilTag data such that GPS location of the obstacles is accurate within 2m.
	Spring	The AGV shall be able to localize itself within the area map with 5m accuracy
	Spring	The AGV shall provide camera feed to the user at a refresh rate of 60 Hz

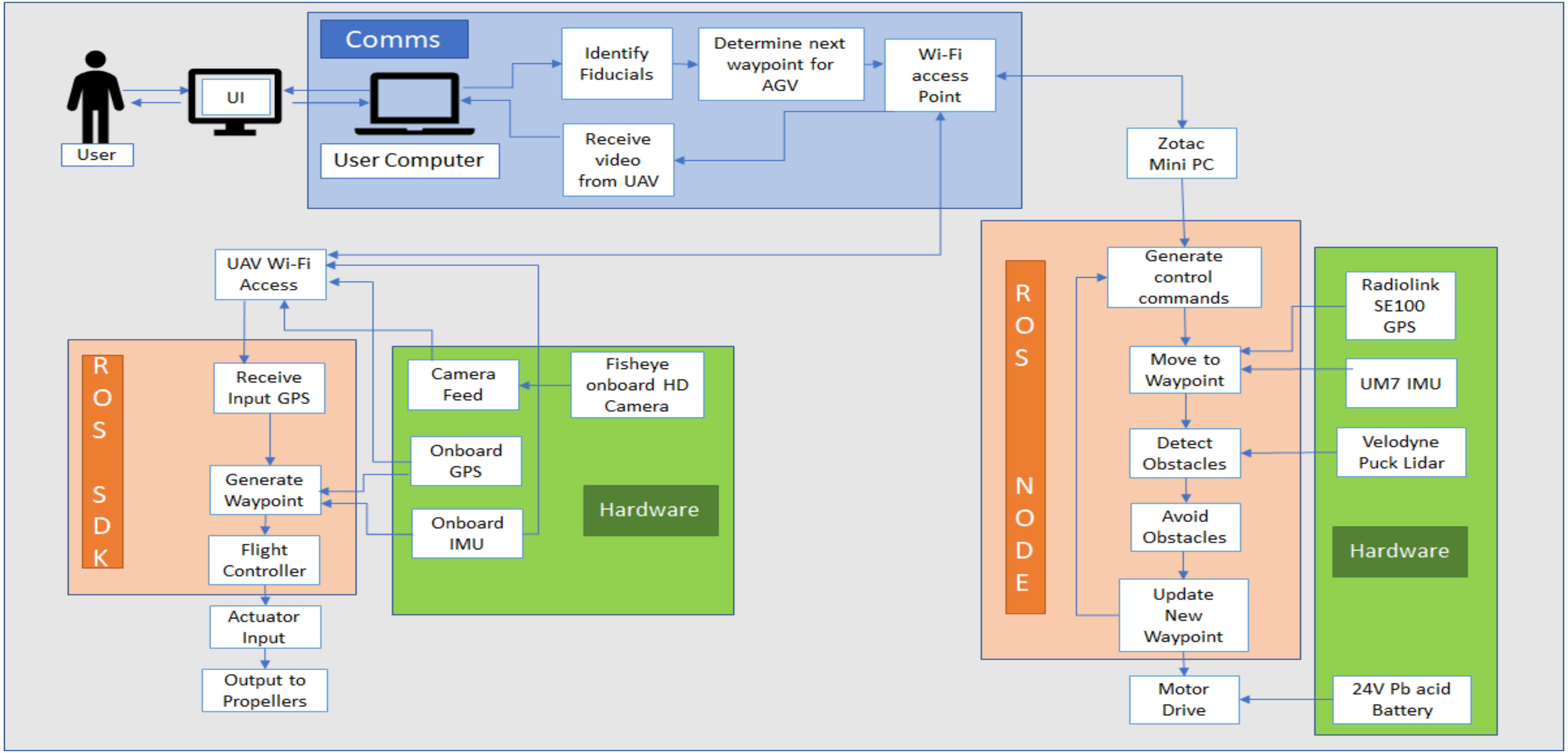
System-level requirements
Non-Functional

		Non- Functional Requirements
Mandatory	Fall	The UAV shall be able to fly for the entire mission
	Fall	The UAV shall have real-time communication with the user
	Fall	The system shall be able to be easily transported from one station to other
	Fall	The system shall have at least 1 UAV and 1 AGV
	Spring	The system should be easy to setup and operate
Desirable	Spring	The system shall cost under $5000
	Spring	The system shall have 2 UAV and 2 UGV
	Spring	The system should be able to operate in uneven terrain
	Spring	The system serves for future research purpose of the sponsor
	Spring	The system shall provide Lidar data for future research purposes

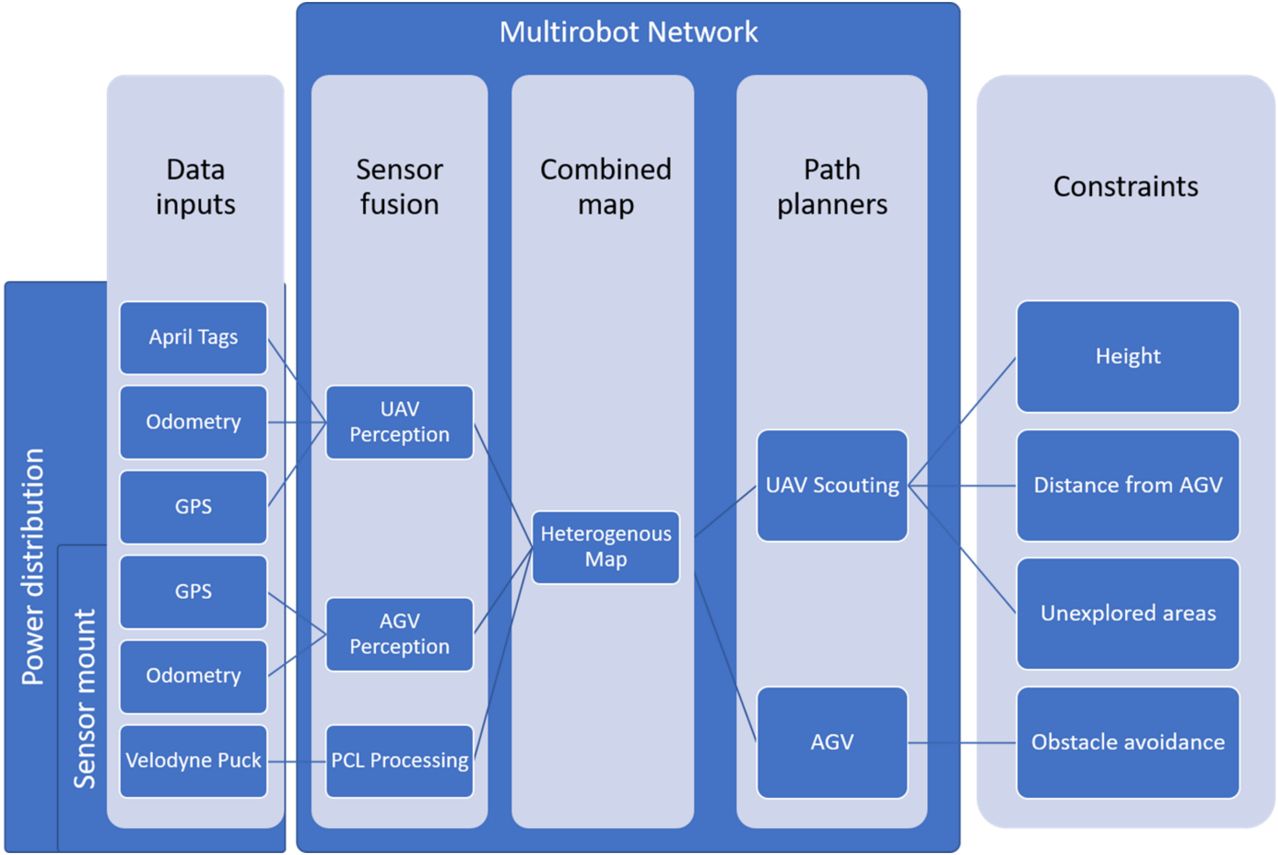
Functional Architecture



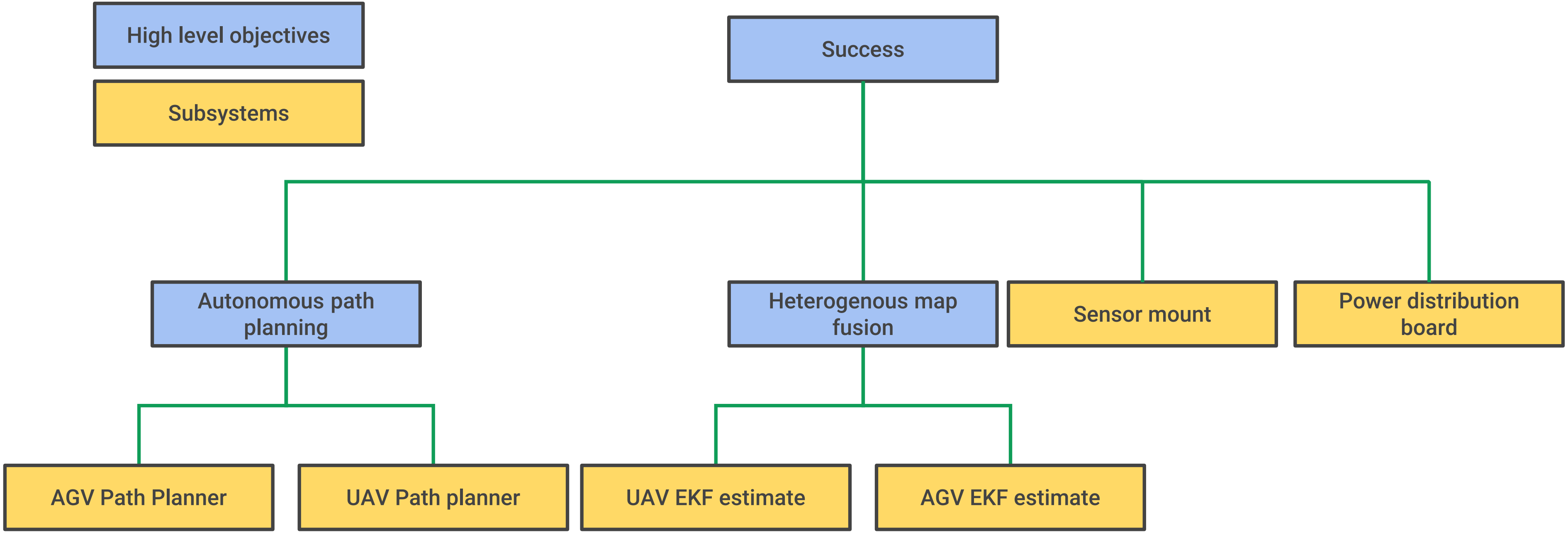
Cyberphysical Architecture



System description



System description



AGV Subsystem

Component Finalization

Husky

um7 IMU

GPS - SE 100

Zotac Mini-PC

1. System Component finalization
   - 1.1 ~~Platform for AGV~~
   - 1.2 Perception system sensors
   - 1.3 ~~Sensors for localization system.~~
   - 1.4 ~~Procurement batteries~~ and components.

- The sensor mount will house all the AGV sensors and provide place for April Tag
  - Provides outpost for GPS to get clear signal
  - Let's Velodyne Puck detect obstacles unobstructed
  - Large and open platform for carrying UAV and to place an April Tag
- Completed
  - Have constructed a complete CAD model with Husky, Velodyne Puck, GPS, Camera, IMU, Mini-PC, Battery and their mounts.
- Future work
  - Fabricate the sensor mount with aluminum profiles
  - Install the mount onto the Husky AGV

2. AGV Basic hardware & software setup
   2.1 ~~CAD design.~~
   2.2 Fabrication
   2.3 ~~Mini PC - ROS Setup~~
   2.4 Electrical integration sensors
   2.5 ROS sensors driver setup

AGV Subsystem — Sensor Calibration

- Odometry data provides smooth, continuous pose estimates of the AGV w.r.t. home frame
- GPS provides the absolute position of the AGV w.r.t. a global coordinate frame
- IMU will measure the linear and angular motion w.r.t. Home frame.
- EKF combines above data for more accurate estimate of AGV position with regards to the other objects of interest
- Completed
  - Able to read odometry data from Husky AGV
  - Wired a RadioLink SE100 sensor to Arduino and can receive NMEA formatted data over serial
- Future work
  - Convert NMEA data to GPX format
  - Transmit data from Arduino to onboard PC over USB or connect GPS directly to onboard PC
  - Combine the data in an EKF node and test estimation stability and accuracy with respect to GPS coordinates

3. AGV Sensor Calibration & Data Capture
   - 3.1 ~~Outdoor testing with RC.~~
   - 3.2 ~~Odometry data check~~
   - 3.3 LIDAR standalone test
   - 3.4 GPS Static Test
   - 3.5 IMU standalone test

AGV Subsystem

AGV Control

- Need to find the shortest path to destination given a map of its surroundings
  - Needs to avoid known obstacles and dead ends
  - Needs to dynamically update the plan to account for newly discovered paths
- Completed
  - Can operate the AGV with a joystick on the Husky's Mini-pc
  - Tele operation the AGV with a joystick on a remote computer by connecting to roscore over a network
- Future work
  - Receive the goal location from main pc
  - Convert this path into a series of GPS waypoints
  - Convert waypoints into cmd_vel commands
  - Use Velodyne to detect obstacles
  - Plan paths around the obstacle and navigate.

4. AGV control
   - 4.1 Basic Control Stack
   - 4.2 Tele-op with Remote-PC
   - 4.3 GPS based navigation

5. Sensor Integration
   - 5.1 Sensor software development
   - 5.2 LIDAR obstacle detection
   - 5.3 Path Planning - virtual obstacles
   - 5.4 Localization - GPS + Odometry

UAV Subsystem — Setup & Sensor calibration

- Completed
  - Can tele-operate the UAV with a joystick remotely from a laptop
  - Can get the video stream to remote PC.
- Future Work
  - GPS accuracy testing
  - IMU standalone testing

1. System Component finalization
   1.1 ~~Platform for UAV~~
   1.2 ~~Procurement~~

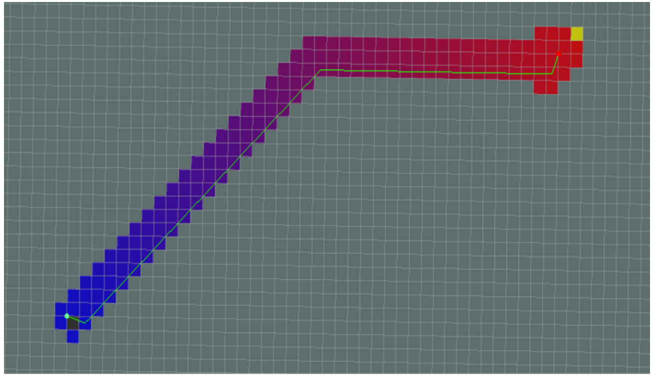
2. Initial UAV platform testing
   2.1 ~~Outdoor flight with RC~~
   2.2 ~~Lower level control SDK~~

3. UAV Basic software setup
   3.1 ~~Remote PC – ROS setup~~
   3.2 ~~ROS – lower level control~~
   3.3 ROS sensors driver setup

4. UAV Sensor Calibration & Data capture
   4.1 GPS Static Test
   4.2 IMU standalone test
   4.3 ~~Video stream to Remote PC~~

- Need a heuristic to guide the UAV to scout the area ahead of the AGV
  - Cannot go too far to lose visual sight of the AGV in order to maintain relative localization
  - Cannot go too high to maintain accuracy of April Tags
  - Needs go toward the targeted destination

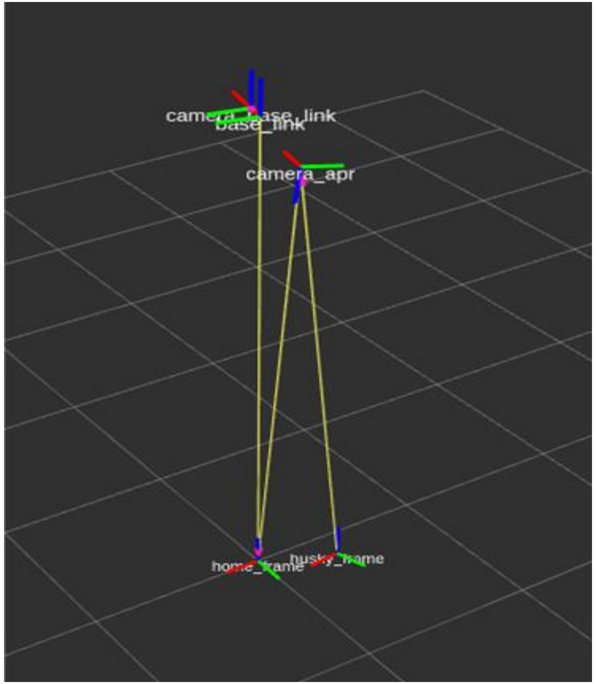
- Future work
  - Generated relative waypoints as areas of interest that satisfy the previously mentioned constraints
  - Convert these waypoints to GPS coordinates
  - Feed GPS coordinates into the Bebop 2 Mission Planner feature



5. Higher Level UAV control
   5.1 Basic Control Stack
   5.2 GPS based navigation

UAV Subsystem Intelligence

- April Tags provides the absolute position of obstacles, paths, and AGV’s w.r.t the UAV
- Odometry data provides smooth, continuous pose estimates of the UAV w.r.t home frame
- GPS provides the absolute position of the UAV w.r.t a global coordinate frame
- EKF combines the above data for a more accurate estimate of the UAV position with regards to the other objects of interest
- Completed
  - Able to read odometry data from Bebop 2 Drone
  - Able to receive GPS data from Bebop 2 Drone
  - Able to localize itself w.r.t 2 April Tags - home frame & Husky frame
- Future work
  - Add GPS data as a custom topic for ROS EKF node
  - Combine all 3 data types in the EKF node
  - Test estimation stability & accuracy w.r.t stationary April Tag targets



6. UAV Intelligence
   6.1 Triggered take-off
   6.2 April tag based localization from video

Subsystem Integration — Communication setup

- Need to host a ROS core over multiple networks
  - Use WiFi adapters and routers to connect to long-distance WiFi networks
  - Allow onboard PC to act as both client and host with multiple adapters
- Completed work
  - Have procured Asus Netgear TPLINK and testing effective range
  - Able to connect computers to a ROS master over short range WAN
- Future work
  - Finalize network adapter
  - Expand ROS network to multiple masters

1. Communication & peripheral setup
   1.1. WiFi access point
   1.2. Boosters antennas
   1.3. Network
   1.4. System Communication layer

Work Breakdown Structure (High-Level)

AGV

1. System Component finalization
2. AGV Basic hardware & software setup
3. AGV Sensor Calibration & Data Capture
4. AGV control
5. Sensor Integration

UAV

1. System Component finalization
2. Initial UAV platform testing
3. UAV Basic Software setup
4. UAV Sensor Calibration & Data Capture
5. Higher Level UAV control
6. UAV intelligence

SYSTEM INTEGRATION

1. Communication & peripheral setup
2. Integration test for fall demo
3. Integration test for spring demo

PROJECT MANAGEMENT

1. Prepare task Gantt
2. Procure Components
3. Communication to Stakeholders
4. Track Work Progress
5. Risk Mitigation

Work Breakdown Structure (Detailed)

AGV

1. System Component finalization
    1.1 Platform for AGV
    1.2 Perception system sensors
    1.3 Sensors for localization system.
    1.4 Procurement batteries and components.
2. AGV Basic hardware & software setup
    2.1 CAD design.
    2.2 Fabrication
    2.3 Mini-PC - ROS Setup
    2.4 Electrical integration sensors
    2.5 ROS sensors driver setup
3. AGV Sensor Calibration & Data Capture
    3.1 Outdoor testing with RC.
    3.2 Odometry data check
    3.3 LIDAR standalone test
    3.4 GPS Static Test
    3.5 IMU standalone test
4. AGV control
    4.1 Basic Control Stack
    4.2 Tele-op with Remote-PC
    4.3 GPS based navigation
5. Sensor Integration
    5.1 Sensor software development
    5.2 LiDAR obstacle detection
    5.3 Path Planning - virtual obstacles
    5.4 Localization - GPS + Odometry

UAV

1. System Component finalization
    1.1 Platform for UAV
    1.2 Procurement
2. Initial UAV platform testing
    2.1 Outdoor flight test with RC
    2.2 Lower level control with SDK
3. UAV Basic software setup
    3.1 Remote-PC - ROS setup
    3.2 ROS - lower level control.
    3.3 ROS sensors driver setup
4. UAV Sensor Calibration & Data Capture
    4.1 GPS Static Test.
    4.2. IMU standalone test
    4.3. Video stream to Remote-PC
5. Higher Level UAV control
    5.1 Basic Control Stack
    5.2. GPS based navigation
6. UAV intelligence
    6.1 Triggered take-off
    6.2. April tag based localization from video

System Integration

1. Communication & peripheral setup
    1.1. WiFi access point
    1.2. Boosters antennas
    1.3. Network
    1.4. System Communication layer
2. Integration test for fall demo
    2.1. Network reliability test
    2.2 AGV Tele-op test
    2.3 UAV Tele-op test
    2.4 April tag based-localization
    2.5 UAV GPS based navigation test
    2.6 System testing
3. Integration test for spring demo
    3.1. Path Planning with obstacle avoidance
    3.2. AGV Motion Planning
    3.3. Software stack integration
    3.4. AGV Video feed
    3.5. System GUI

PROJECT MANAGEMENT

1. Prepare task Gantt
2. Procure Components
3. Communication to Stakeholders
4. Track Work Progress
5. Risk Mitigation

Schedule - FVE

	Sept		October								November								
Tasks	21-28	29-30	1-7	8-13	15-19	20	21-26	27	28-30	31	1-2	3	4-9	10	11-21	22	23-28	28-29	30
No. of days	8	2	7	6	5	1	6	1	3	1	2	1	6	1	11	1	6	2	1
AGV																			
System Component finalisation		1.1	1.4				1.2-1.3												
Basic hardware & software Dev				2.3			2.1		2.2		2.4								
sensor calibration & Data capture					3.1								3.2,3.5		3.3, 3.4				
Control															4.3				
sensor integration																			
UAV																			
System Component finalisation				1.1-1.2															
Initial UAV testing					2.1-2.2														
Basic ROS sensor software Dev					3.1-3.2		3.3		3.3										
sensor calibration & Data capture											4.1		4.2		4.2, 4.3				
Higher UAV Control											5.1		5.1		5.2				
UAV Intelligence																			
System Integration																			
Communication & peripheral setup													1.1		1.2,1.3				
Integrating system for FVE																	Testing for FVE		
Integrating system for SVE																			

Schedule - SVE

	January		February		March		April	
Tasks	**1-15**	**16-31**	**1-15**	**16-28**	**1-15**	**16-31**	**1-15**	**16-30**
No. of days	**15**	**16**	**15**	**13**	**15**	**16**	**15**	**15**
AGV								
System Component finalisation								
Basic hardware & software Dev								
sensor calibration & Data capture								
Control	4.1	4.2						
sensor integration			5.1	5.2	5.3	5.4		
UAV								
System Component finalisation								
Initial UAV testing								
Basic ROS sensor software Dev								
sensor calibration & Data capture								
Higher UAV Control								
UAV Intelligence		6.1	6.2	6.2				
System Integration								
Communication & peripheral setup				1.4				
Integrating system for FVE								
Integrating system for SVE							Testing for SVE	

Planned vs Actual Schedule

Subsystem	Task No	Planned	Comments
AGV	1.1,1.3,1.4	Platform, localization sensor and other peripherals finalise and procure	Completed
	1.2	Perception sensors	Yet to finalize and procure
	2.1-2.2	CAD Design and fabrication	CAD completed & fabrication is partially done.
UAV	1.1-1.2	Platform finalization and procurement	Completed
	2.1-2.2	Outdoor flight test & low level control	Completed
	3.1-3.2	ROS Setup & ROS low level control	Completed
	3.3	ROS sensors driver setup	Delayed
	6.2	April tag localization	Ahead of schedule, initially planned for SVE

Higher Level Schedule

Date	PR	Milestone	Testing
3rd Nov		Fabrication of assembly (Basic)	Physical Inspection of complete assembly
5th Nov		Power distribution system finalisation	Submit final PCB for printing
9th Nov		Localization based on April tags (Basic)	Identifying 2 april tags
9th Nov		Complete fabrication and electrical wiring	Physical Inspection of system
10th Nov	**PR3**		
14th Nov		Husky Teleop and System Network	Demonstrating teleop of Husky in Lab & Communication over network
15th Nov		GPS based UAV navigation	Demonstrating GPS based flight of UAV
18th Nov		Localization based on April tags (Complete)	Multiple April tags detection & relative pose estimation
22th Nov	**PR4**		
30th Nov	**PR5**		

Higher Level Schedule

Date	PR	Milestone	Test method
Jan 31	Spring PR 1	Location fusion & UAV Intelligence	Check difference in relative location between locations and test UAV path planning heuristics when AGV is teleopereated
Feb 28	Spring PR 2	Obstacle detection with LIDAR	Success rate of AGV to avoid static obstacles in its path
Mar 27	Spring PR 3	AGV Path Planning and localization	Test AGVs ability to dynamically generate and follow AGV waypoints from combined map
Apr 22	Final Demonstration	Complete System integration	Refer to SVE test plan

Fall Validation Experiment

Location : Football Field

- Size: 50m X 50m
- Floor surface: Grass

Setup:

- April tags : 11.7 x 16.5 in (Count : 12)
- One UGV (Husky)
- One UAV (Bebop 2)
- One laptop connected wirelessly to UGV mini-PC
- One laptop connected wirelessly to UAV
- Five team Members

Fall Validation Experiment

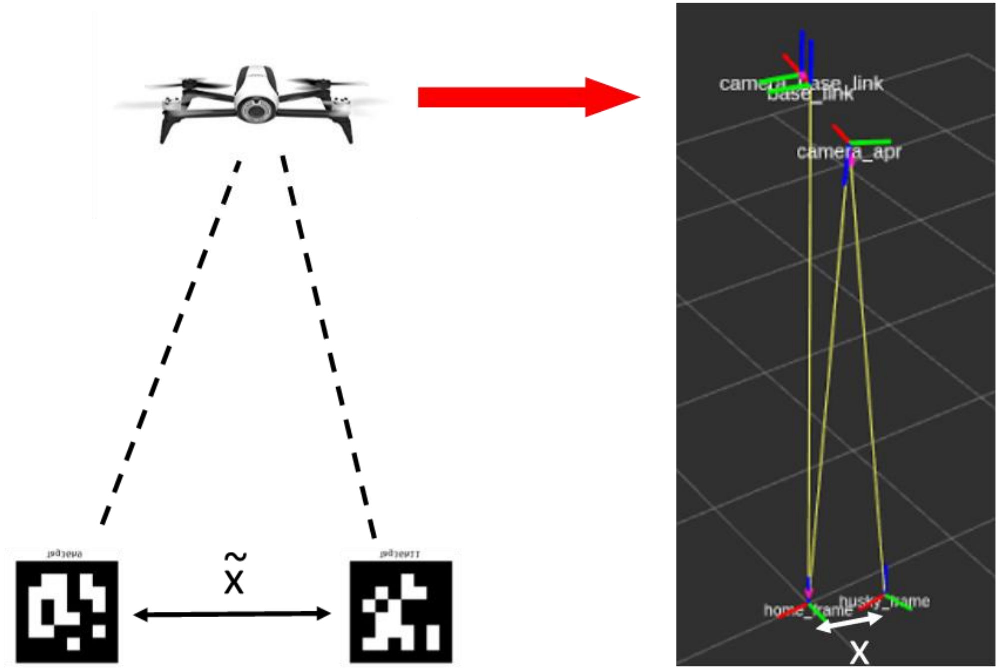
Test A: April Tags Localization test

Objective: To calculate the distance between two April tags from the video captured by the drone.

Test Sequence:

Test Sequence	Description	Performance Measures
A.1	Place UAV on the AGV. Give take-off command (teleop).	
A.2	UAV takes off and transmits video	
A.3	Detect two April tags placed on the ground through the camera feed of UAV	Accurately detect both the markers
A.4	Compute the distance between the two tags	Accuracy of distance computed with respect to manual measurement (+- 30cm)

Fall Validation Experiment



Fall Validation Experiment

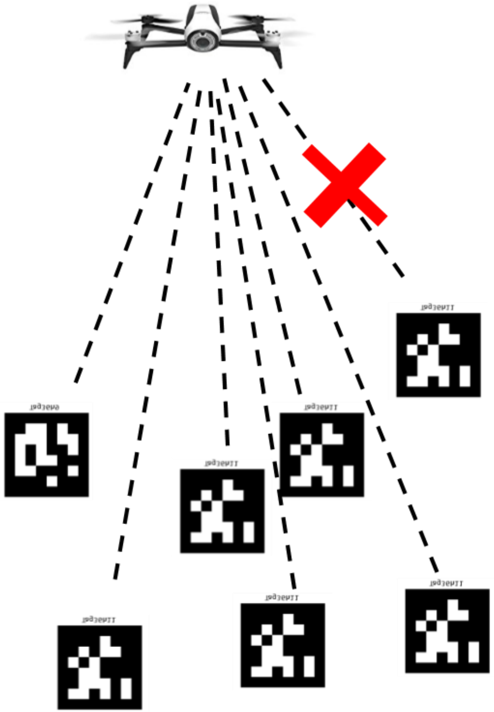
Test B: April Tags Detection test

Objective: To detect all the April tags placed in the test environment.

Test Sequence:

Test Sequence	Description	Performance Measures
B.1	Place the UAV on AGV.	
B.2	Teleop AGV to new location and takeoff UAV (teleop)	
B.3	Detect all markers placed in the test environment through camera feed from UAV	Accuracy of number of markers detected (80 %)

Fall Validation Experiment



Fall Validation Experiment

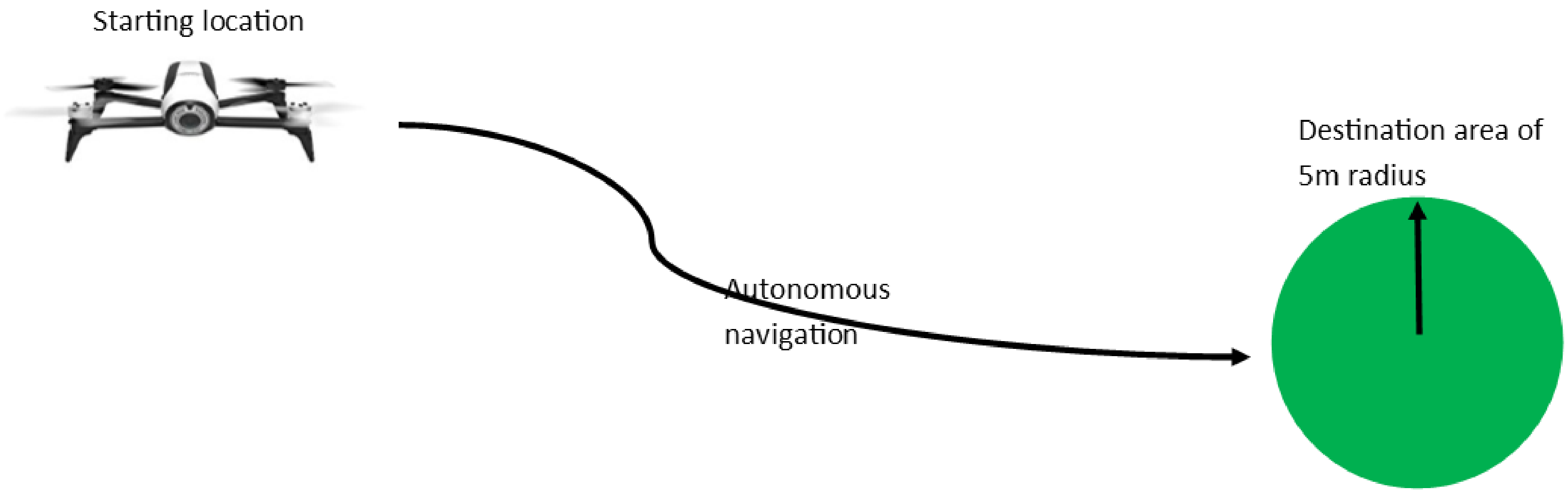
Test C: UAV waypoint navigation test

Objective: To validate the autonomous flight control and waypoint navigation capability of the UAV

Test Sequence:

Test Sequence	Description	Performance Measures
C.1	Feed known GPS location as destination.	
C.2	UAV flies to the given GPS location and lands	Accuracy in reaching desired GPS location (+- 5m tolerance)

Fall Validation Experiment



Spring Validation Experiment

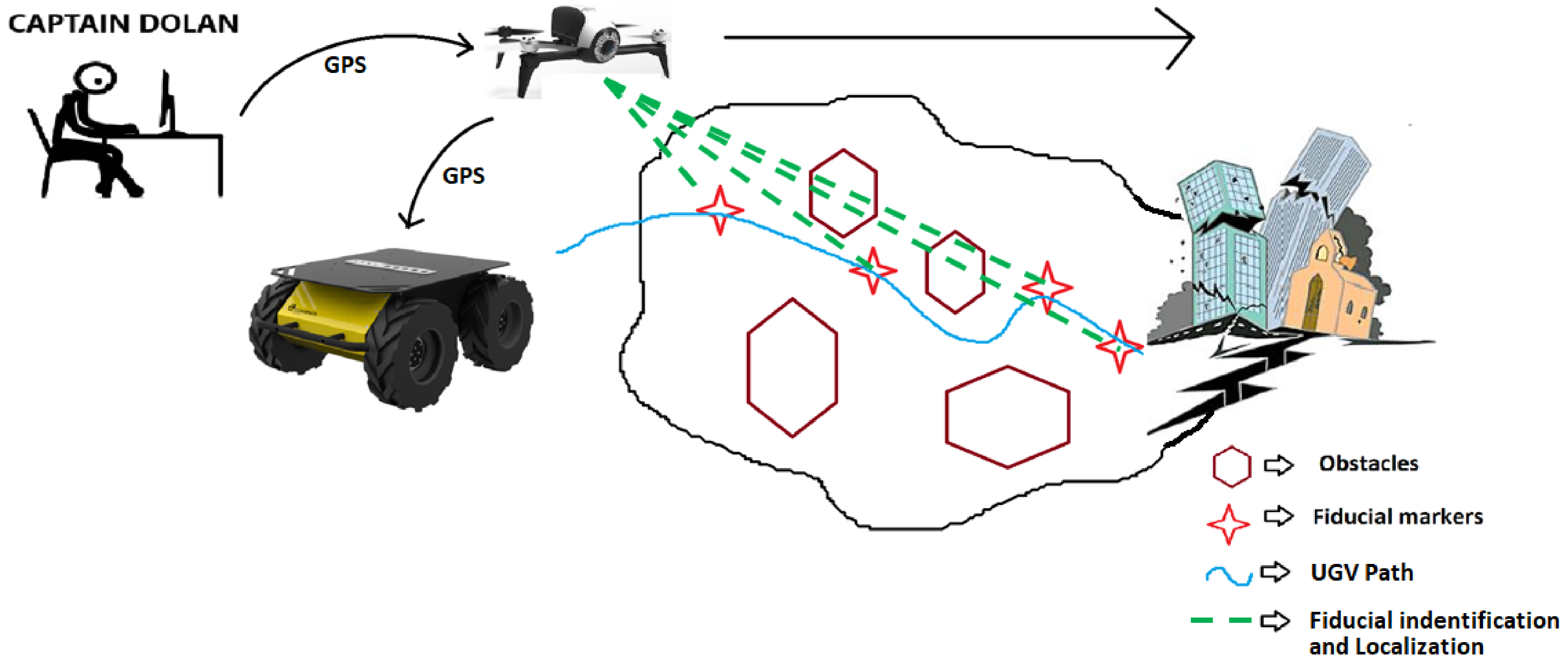
Location : Football Field

- Size: 50m X 50m
- Floor surface: Grass

Setup:

- April tags : 11.7 x 16.5 in (Count : 12)
- Obstacles : 50 X 50 X 50 cm
- One UGV (Husky)
- One UAV (Bebop 2)
- One laptop connected wirelessly to UGV mini-PC
- One laptop connected wirelessly to UAV
- Five team Members

Spring Validation Experiment

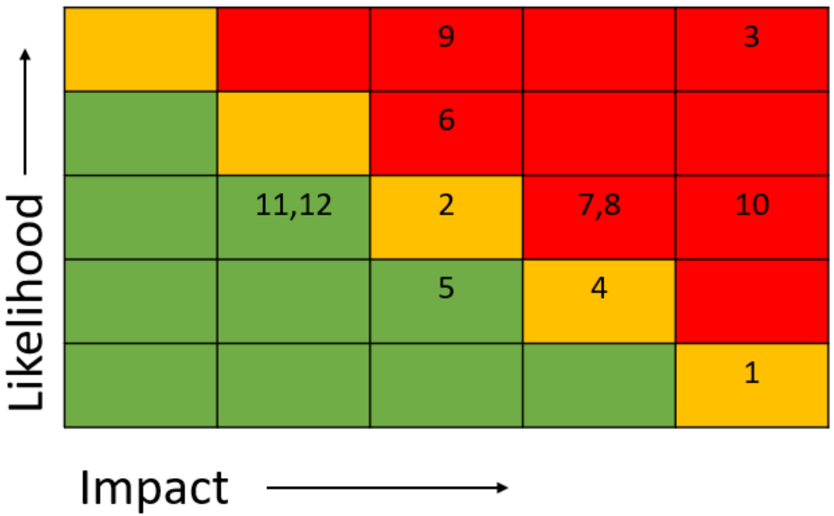


Spring Validation Experiment

Test Sequence	Description	Performance Measures
A.1	Place UAV on the AGV. Give GPS input to AGV.	
A.2	Autonomous navigation of AGV to the given location (without obstacles)	Accuracy in reaching desired GPS location (+- 3m tolerance)
A.3	AGV triggers the UAV, UAV takes off	
A.4	UAV hovers around the AGV at the given height and transmits video	Accuracy in reaching given height (+- 1m tolerance), stays within 10m radius of AGV
A.5	Computation of April tag location and input to AGV	
A.6	AGV navigates to given location avoiding static obstacles	Avoid obstacles greater than 50 X 50 X 50 cm, 80% of the time
A.7	AGV reaches the given location of the April Tag	Accuracy in reaching desired Tag location (+- 2m tolerance)
A.8	AGV reaches to final goal location	Accuracy in reaching final location (+- 3m tolerance)

Risk Management

S.No	Risks Involved	Possibility	Impact	Solution
1	Batteries of AGV arrive Late	LOW	HIGH	Follow up with the vendor
2	UAV Lead time	MEDIUM	MEDIUM	Timely place order and follow up with vendor
3	Higher Cost of Lidar	HIGH	HIGH	Talk to mentor and other departments to borrow
4	Lidar Lead Time	LOW	HIGH	Order Timely
5	Unexpected component requirement	LOW	MEDIUM	Frequent project reviews
6	Outdoor testing problems due to weather	MEDIUM	MEDIUM	Setup for indoor testing subsystems in part.
7	Erroneous data from the chosen sensors	MEDIUM	HIGH	Early testing, debugging and take guidance from experts
8	Subsystem are very complex with lots of development required in limited timeframe	MEDIUM	HIGH	Follow the timelines and changing requirements if necessary
9	Lack of experience within team in control of UAVs	HIGH	MEDIUM	Share the responsibility among members and take help from from experts.
10	System Integration takes too long	HIGH	HIGH	Time management and unit testing
11	Conflicting expectations among stakeholders	MEDIUM	LOW	Strong communication of any development
12	Issues with sponsor for descoping	MEDIUM	LOW	Communicating the timelines of different tasks involved and explaining the complexity of work



Budget

S. No.	Component	Sub-Components	Quantity	Unit Cost		Total Cost
1.	Parrot Bebop 2 drone	Platform	1	$830	Sponsored	$0
2.	Husky	Platform	2	$18600	Sponsored	$0
		GPS	1	$70		$70
		IMU	1	$140	Sponsored	$0
		Mini-PC	2	$200	Inventory & Sponsored	$0
		Li-Ion-Phosphate Battery	2	$405	Sponsored	$0
		Sealed Lead Acid Battery	2	$500	Sponsored	$0
		Camera	2	$200		$200
3.	Velodyne Puck		1	$8000	Sponsored	$0
4.	Ubiquiti BULLET	M5-HP Outdoor	2	$89	Not-Sponsored	$178
	Total					**$448**