Title : COLLABORATION BETWEEN UNMANNED AERIAL AND GROUND VEHICLES FOR SEARCH AND RESCUE MISSIONS

Broader Area of Project: ROBOTICS, CONTROL SYSTEMS

In-house/Industrial: IN-HOUSE

EE 6811: B.E-EEE, Final Year Project

Project Outline

To establish collaboration between an Unmanned Aerial Vehicle (UAV) and an Unmanned Ground Vehicle(UGV) for the purpose of search and rescue missions to enable surveillance and navigation in unknown terrains.

Group No.: B10

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Date:

Project Outcome:

- The concept of automation can be brought into search and rescue missions.
- The implementation will help us in knowing the practical difficulties in performing motion planning, target tracking, executing filter algorithms etc.

References: 1. Video lectures on Aerial Robotics from University of Pennsylvania
2. Theory of Applied Robotics: Kinematics, Dynamics, and Control
3. Probabilistic Robotics by Sebastian Thrun.

Outline

- Motivation
- Brief Literature Review
- Objectives
- Process Flow and Design Steps, and Project Organization
- Overview of Computer Vision, Path planning algorithms
- Hardware
- Experimental Results
- Conclusion and Future work
- References

Motivation

- The first response to a disaster scenario is often critical, and sometimes might prove difficult or hazardous for humans to investigate and respond.
- It is here that we leverage the advantages that robots provide us.
- Often, responding to an earthquake, or nuclear contaminated areas, requires both a strong and sturdy exploratory machine which has a long operating time, while simultaneously requiring agility and being able to smoothly explore as much as possible in as little time.

Motivation

- To this end, one can use teams of robots that collaborate between each other to achieve a common mission, and in time critical response missions, the more equipped and robust the multi-robot collaboration is, the better.

- In this project, we aim to use the collaboration between an unmanned aerial and ground vehicle for search and rescue missions, with both the robots performing what they are best at.

- While the ground vehicle has a long battery life and can carry large payloads and even remove obstacles, the aerial vehicle’s flexibility and rapid movements can be used for quick surveillance and mapping.

Brief Literature Review

- There are many forms of collaborative robotics that have been studied, such as aerial-aerial, ground-ground and aerial-ground collaboration
- These collaborations have also been studied in various contexts, such as precision farming, search and rescue missions, surveying, construction management, etc.
- The seminal papers on ground-aerial vehicle collaboration was put forth by Michael et al (2012), Mueggler et al (2014), and Delmerico et al (2016).
- The work done by Schneider et al (2015) was instrumental in establishing standards and bench-marks for search and rescue collaborative robotics.

Brief Literature Review

- Our project is a modified version of the work done by Mueggler et al (2014), where we keep our environments in 2D and have predefined obstacles.

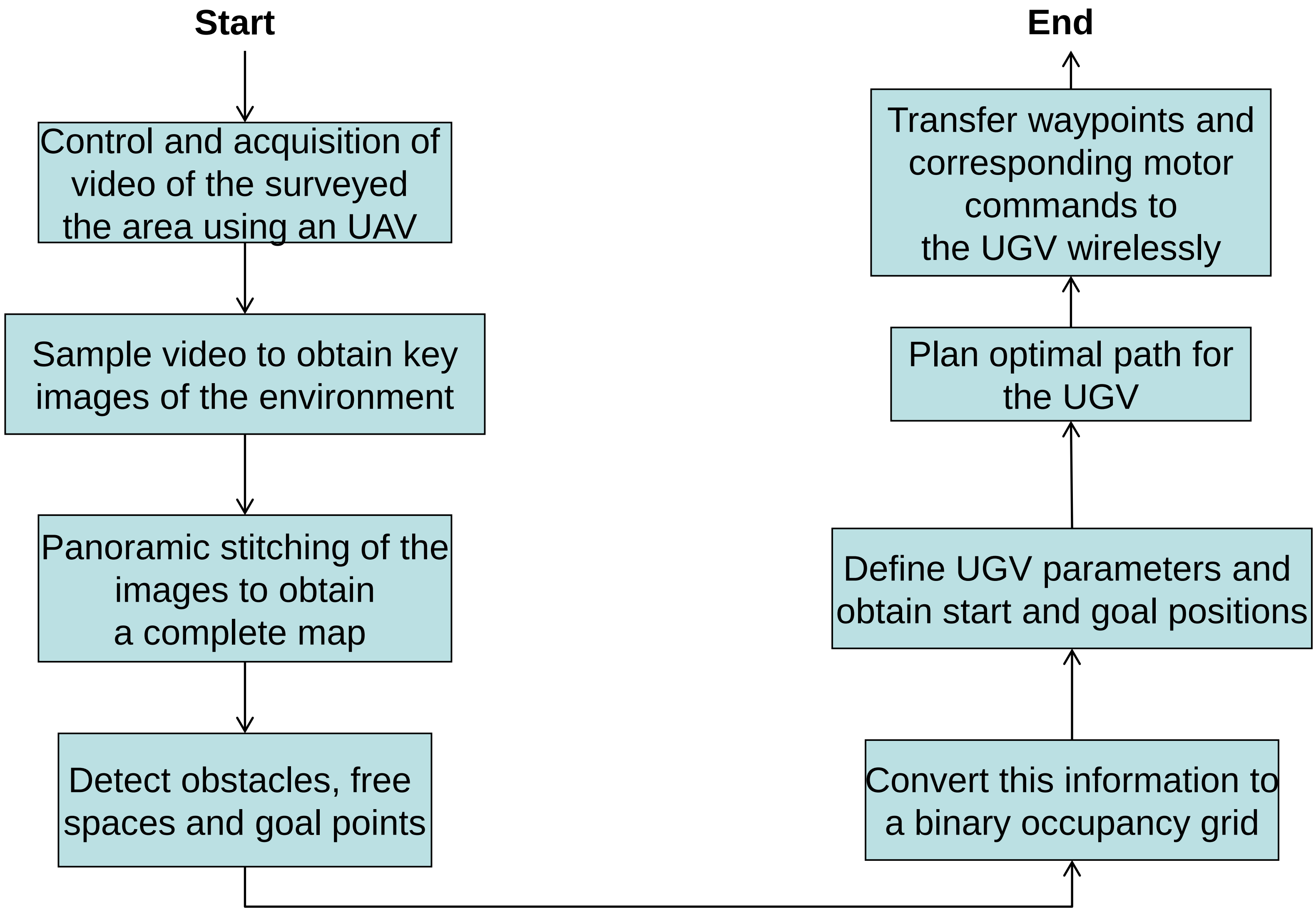
- Michael et al (2012) were the first ones to use a collaborative system to map an actual earthquake bound area, but their work only mapped the system and did not rescue anyone.

- The current state-of-the-art of collaborative search and rescue robotics is the work of Delmerico et al (2016), whose work has included online terrain mapping and active exploration for the aerial vehicle, resulting in dense 3D reconstructions of the environment.

Objectives

- To use a UAV to sequentially map the given area that needs to be surveyed by flying over the area through the specific waypoints.
- To use the video footage obtained from the UAV and sample the footage strategically and obtain images to be stitched
- Use a suitable computer vision technique to stitch the images
- Use the stitched images to identify and localize obstacles and keypoints where people are stuck, and identify the number of people
- Transform this information into a binary occupancy grid for motion planning of the UGV
- Use a suitable motion planning strategy for the UGV to execute
- Plan a mission in such a way that the total time for the execution of the mission is minimized, taking into account distances to be travelled and number of people to save.

Process Flow



Project Design Steps

- Buy an unmanned aerial vehicle (UAV)
- Construct an unmanned ground vehicle (UGV)
- Establish wireless connection between UAV, UGV and master node
- Setup a mock disaster zone
- Design and implement corresponding Computer Vision and Path planning algorithms

Project organization

Project Team responsibilities	Project Budget
Member1: Obtaining Binary Occupancy Grid using Unmanned Aerial Vehicle	**Budget of our project** : INR 25,000
Member2: Performing Path Planning on the obtained Occupancy Grid.	**Tools to be used for the project:** Software: MATLAB, ARDUINO IDE, Raspbian OS Hardware: Basic components to build a Ground Vehicle, Raspberry Pi 3B
Member3: Obtaining the desired wheel commands for the UGV to traverse the path.	

Results are presented as **videos and hardware demonstrations.**

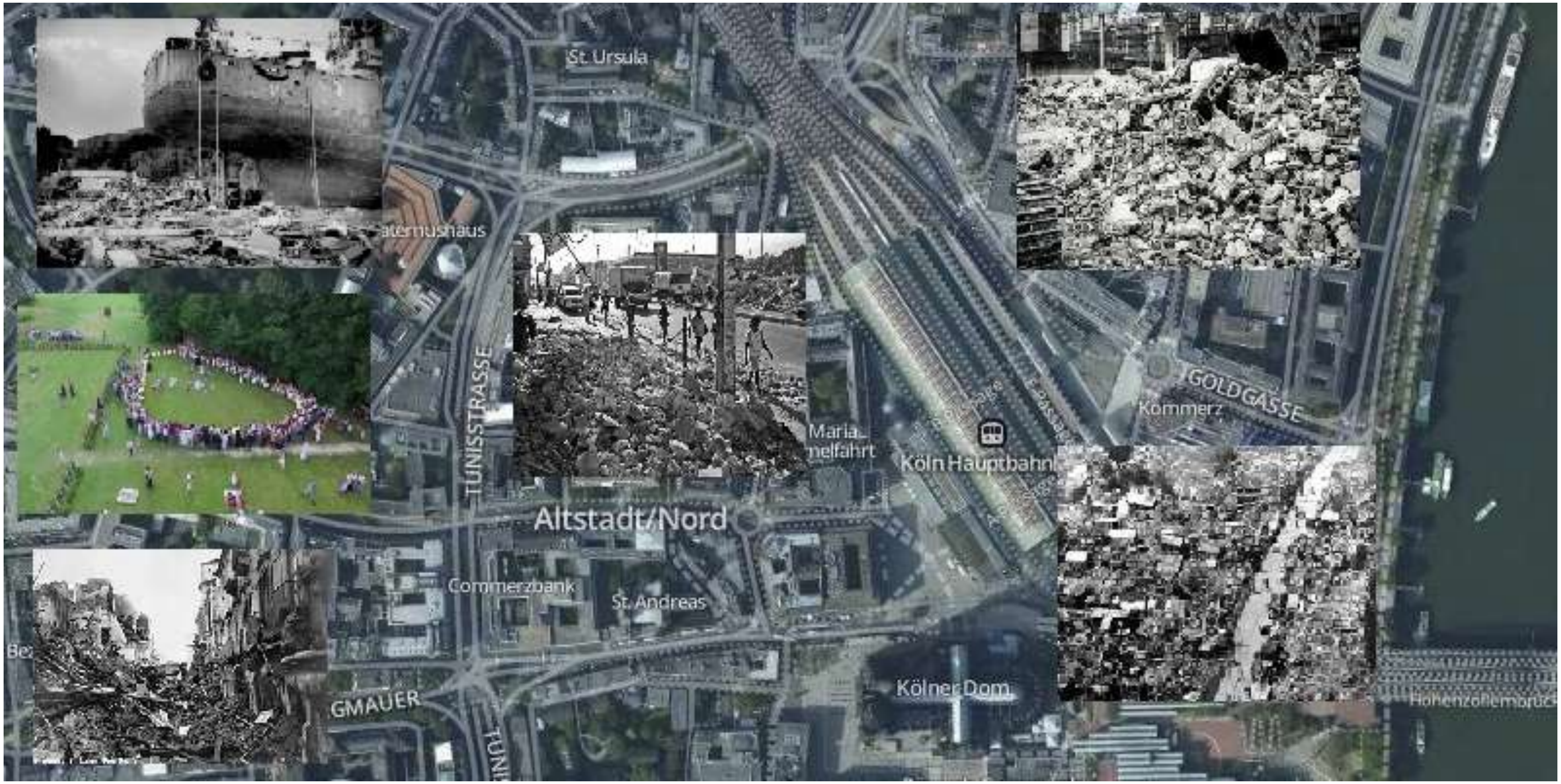
Computer Vision and Path Planning algorithms

Sampling Images from Video

- The video obtained from the UAV is provided as input to MATLAB
- With the knowledge of the frame rate of the video, the speed of motion of the UAV, one can specify when to sample the video, and store the image in an array.
- Example: A test video of a shuttle in MATLAB, with 121 frames at a 30 fps, sampled at every 10 frames



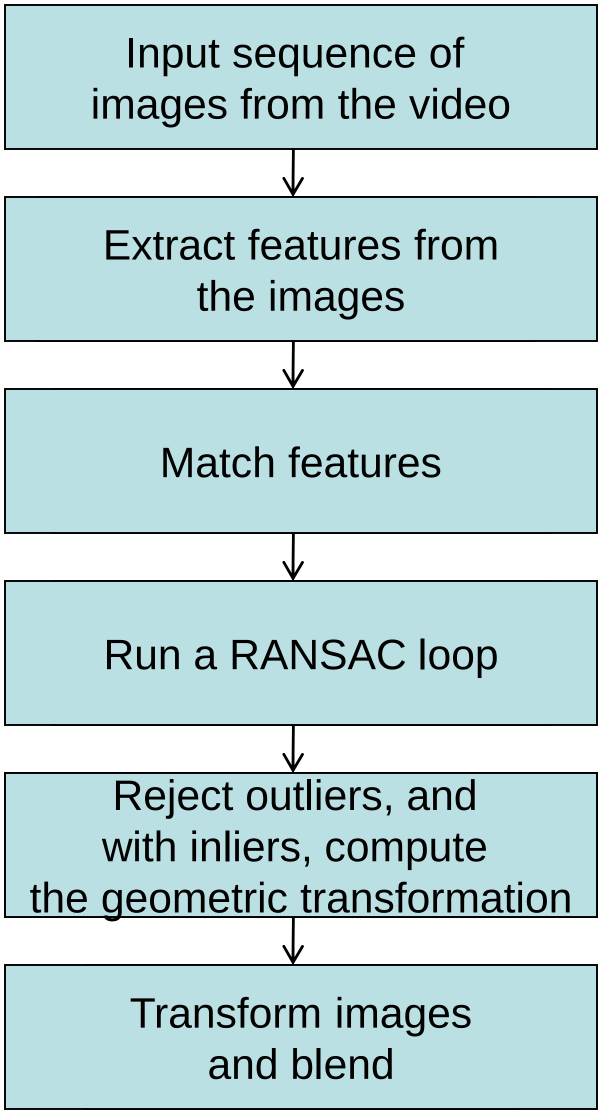
Our test sets



Courtesy: Google Maps and Google Images

Computer Vision and Path Planning algorithms

Panoramic Stitching

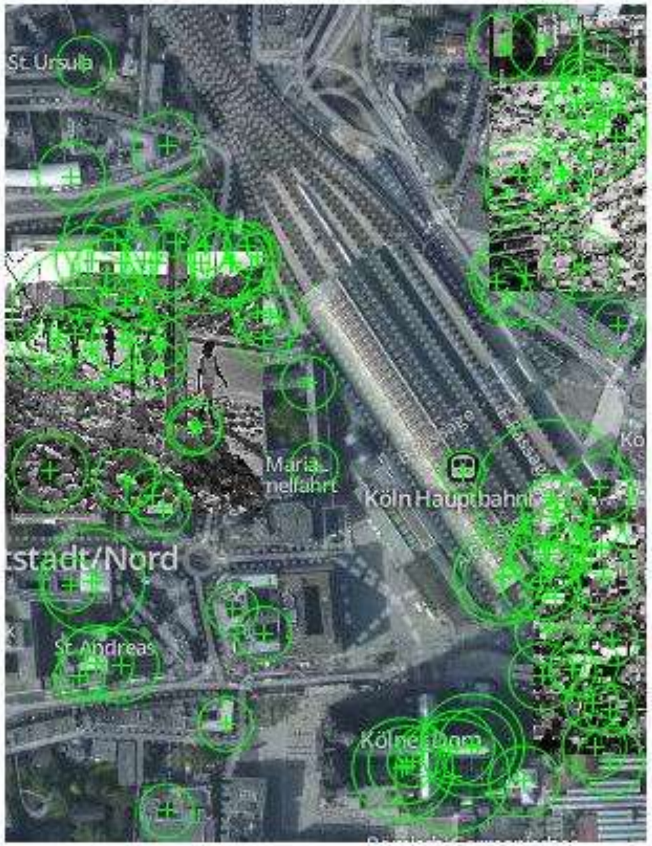


Computer Vision and Path Planning algorithms

Panoramic Stitching

Panoramic Stitching

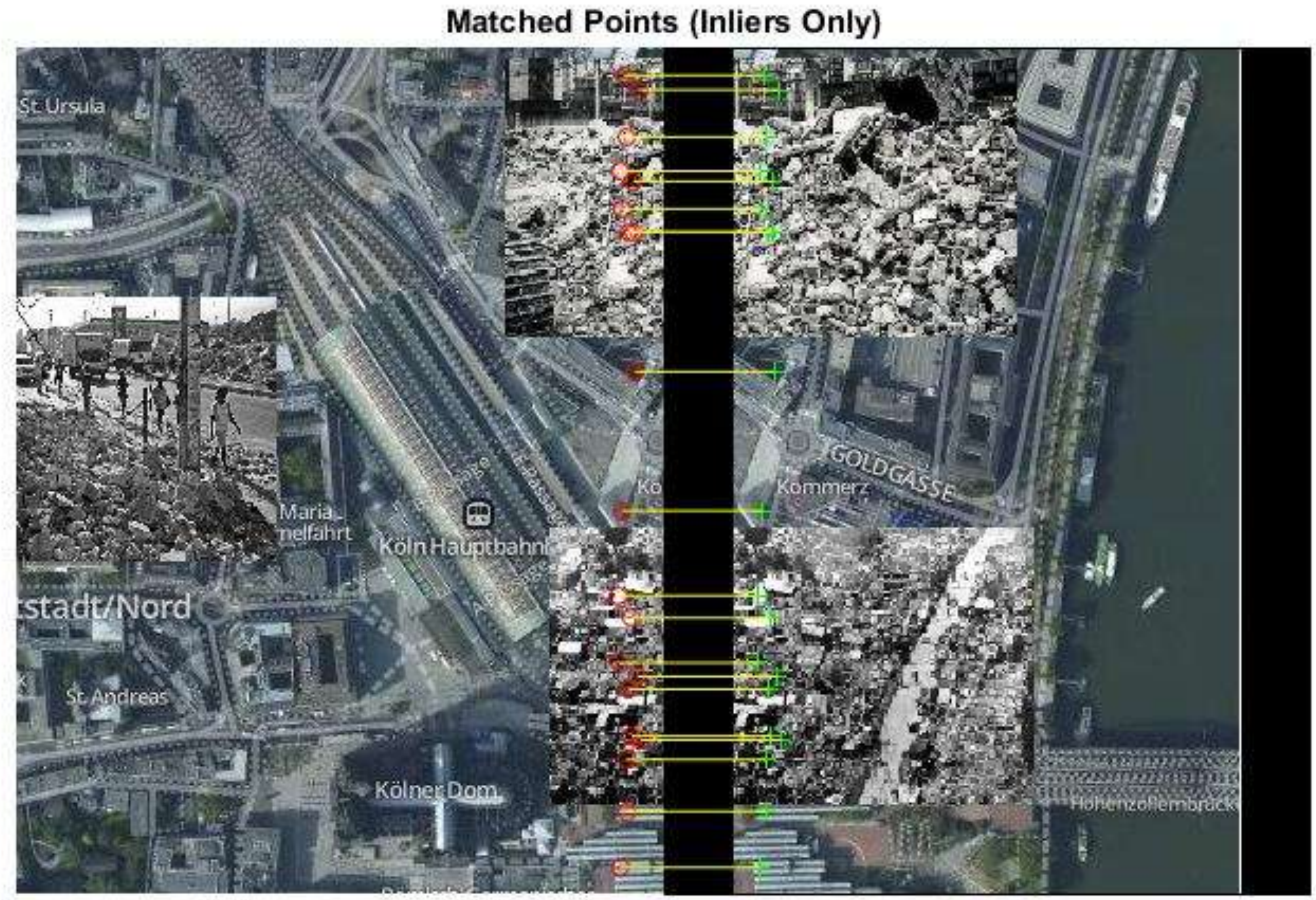
100 Strongest Feature Points from image 1



100 Strongest Feature Points from Image 2

Computer Vision and Path Planning algorithms

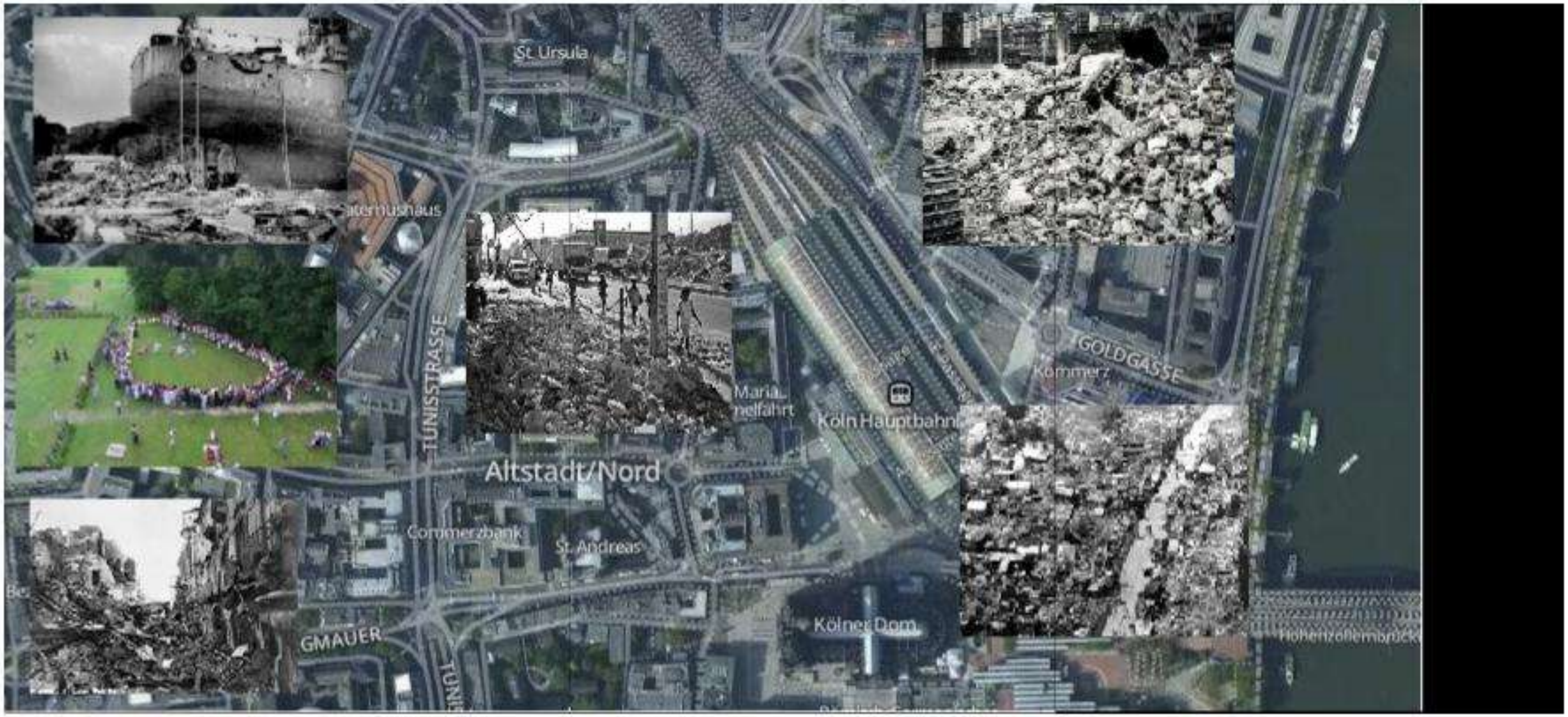
Panoramic Stitching



Computer Vision and Path Planning algorithms

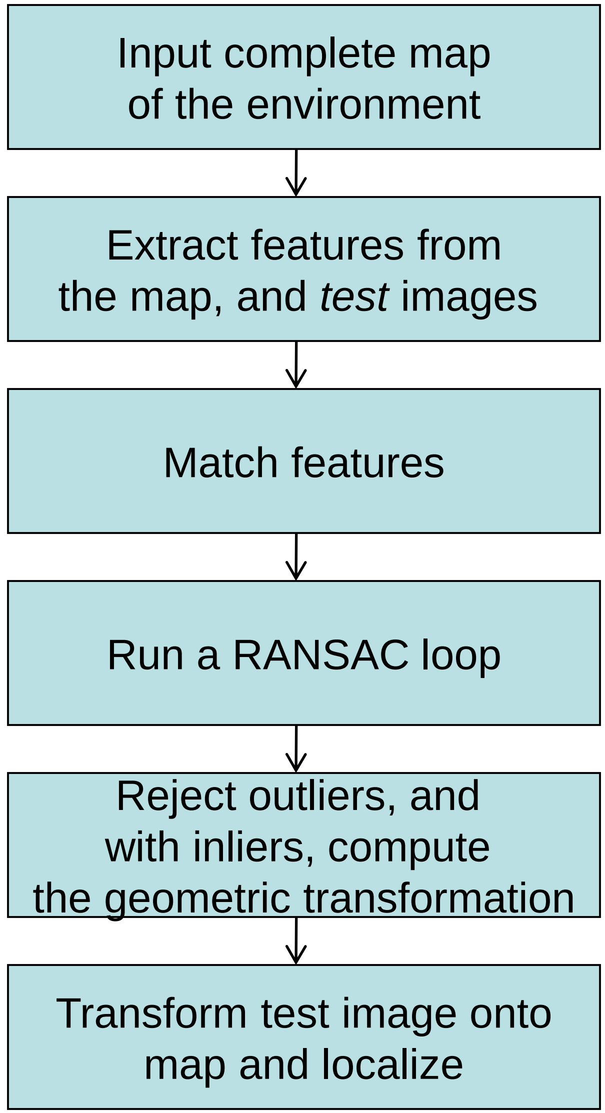
Panoramic Stitching

Final Panorama



Computer Vision and Path Planning algorithms

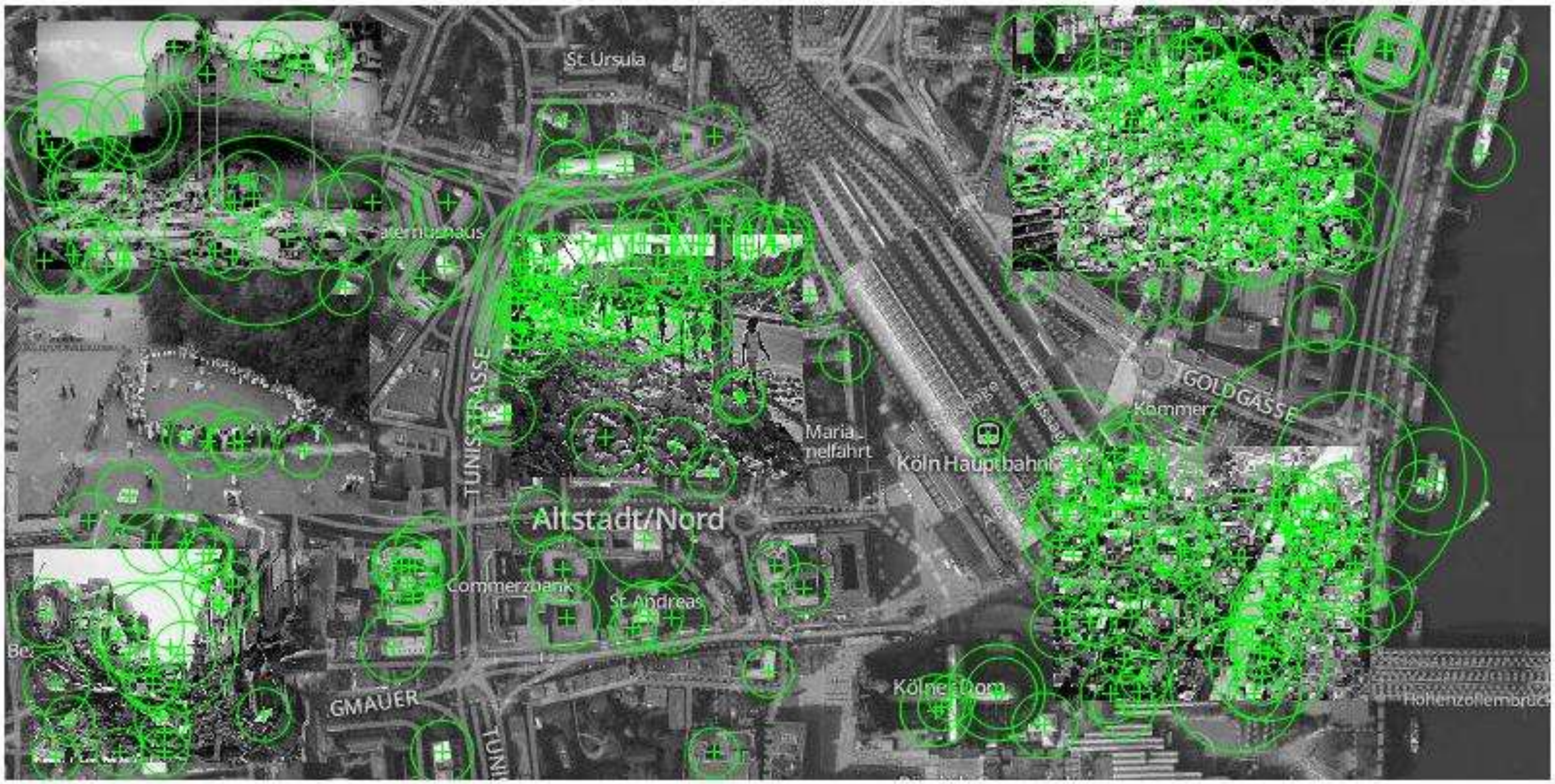
Object Detection



Computer Vision and Path Planning algorithms

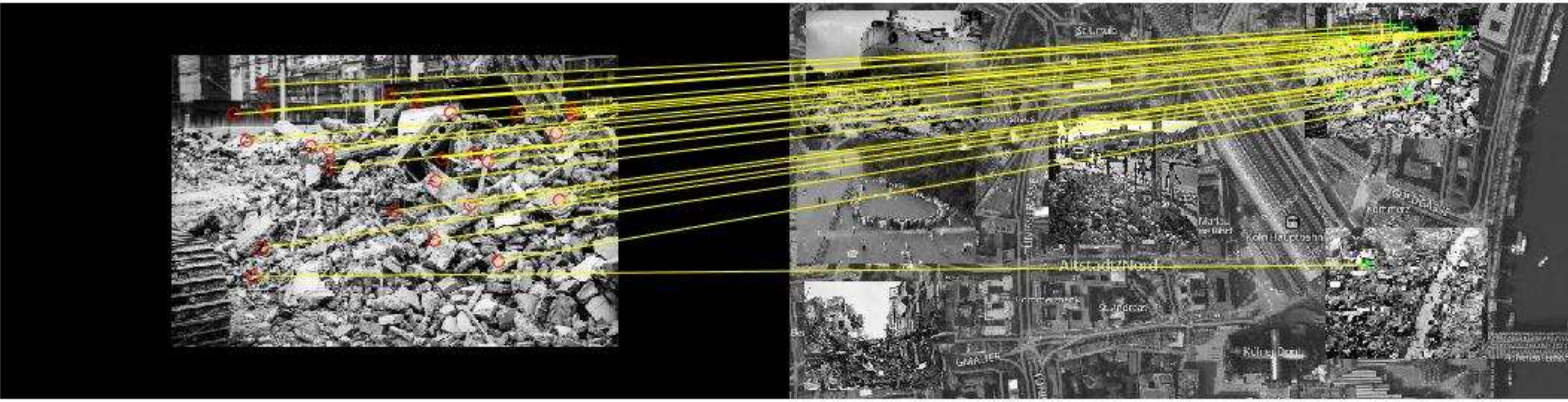
Object Detection

300 Strongest Feature Points from the map

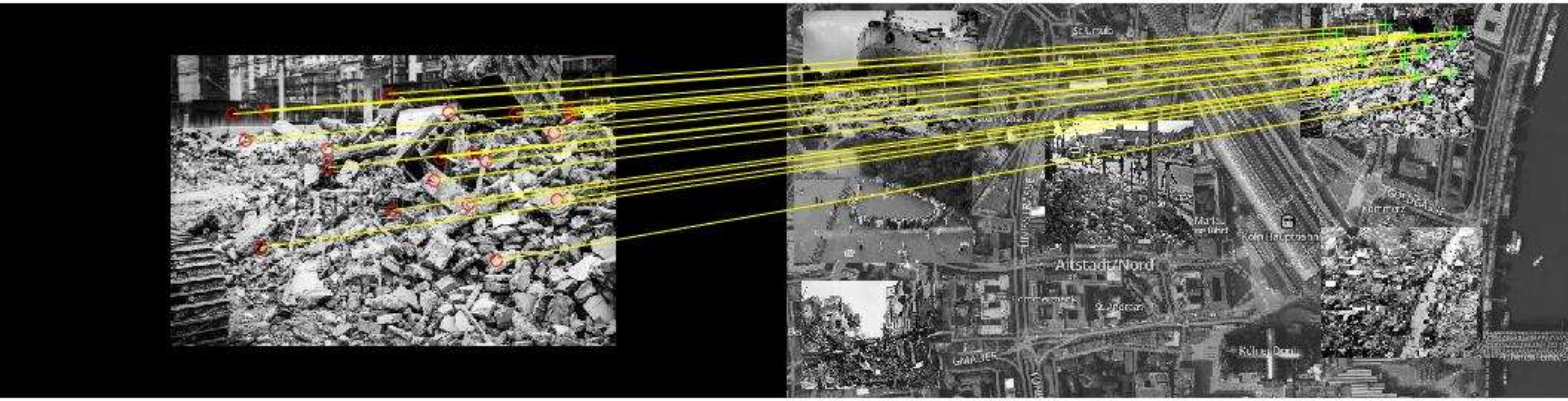


Object Detection

Matched Points (Including Outliers)



Matched Points (Inliers Only)



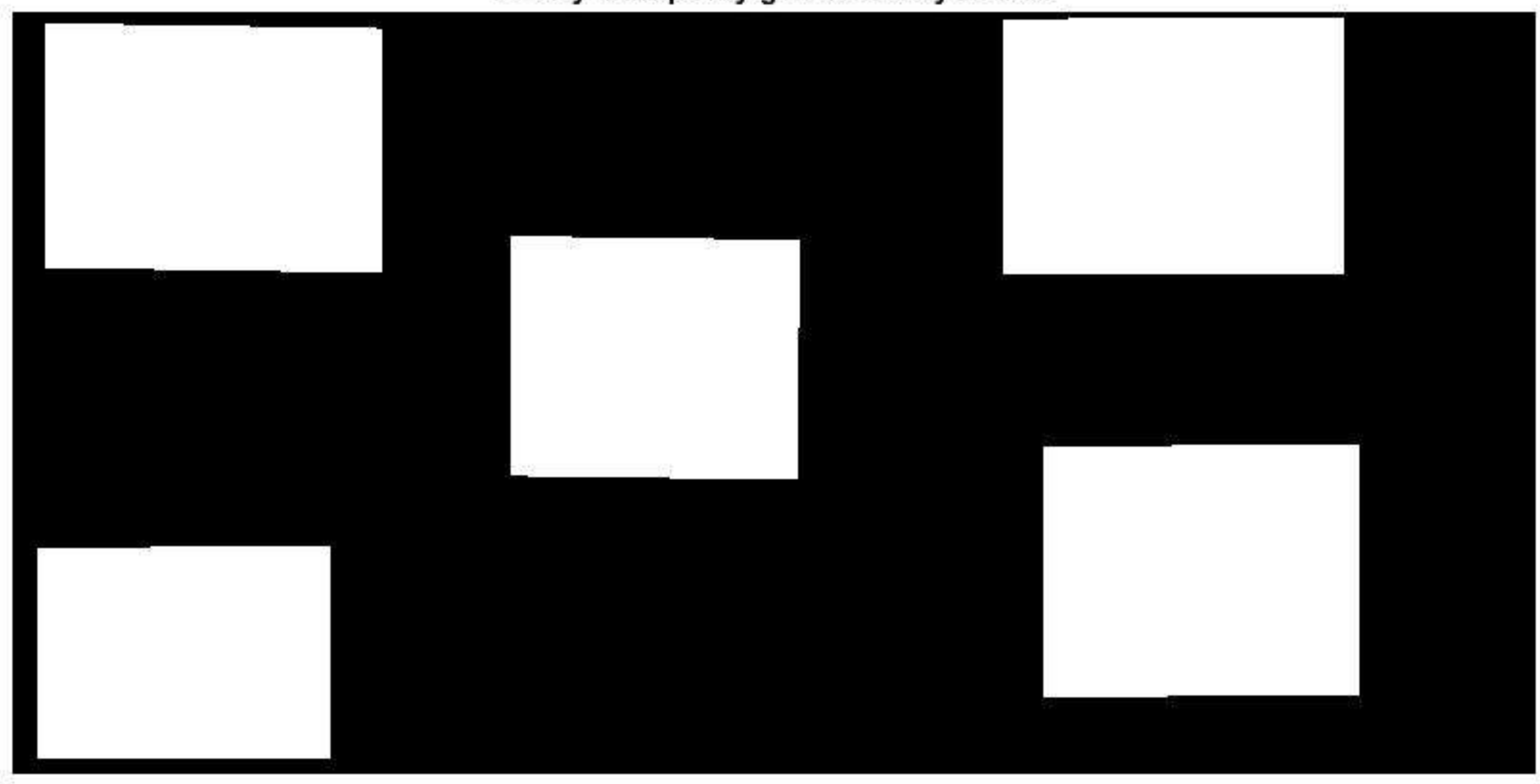
Computer Vision and Path Planning algorithms

Object Detection

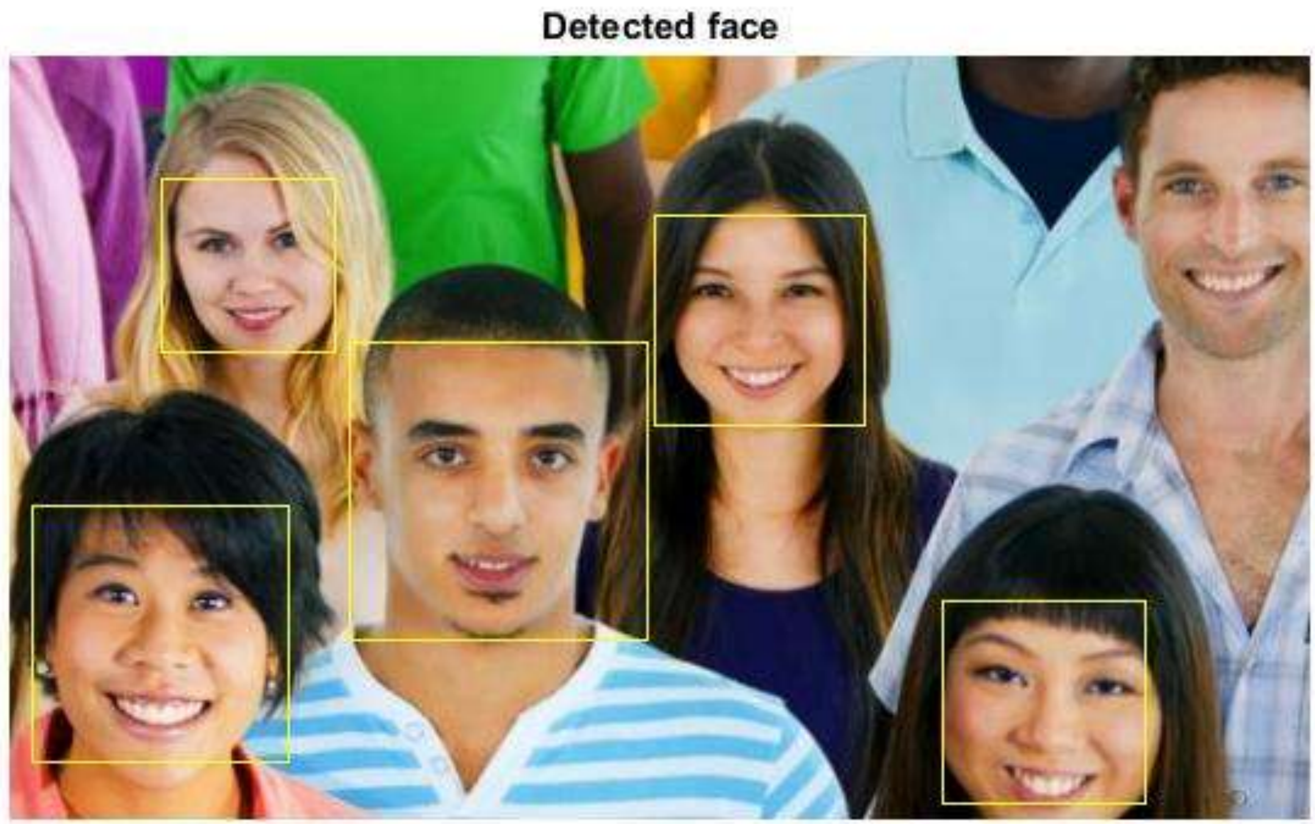
Computer Vision and Path Planning algorithms

Binary Occupancy Grid

Binary Occupancy grid of surveyed area

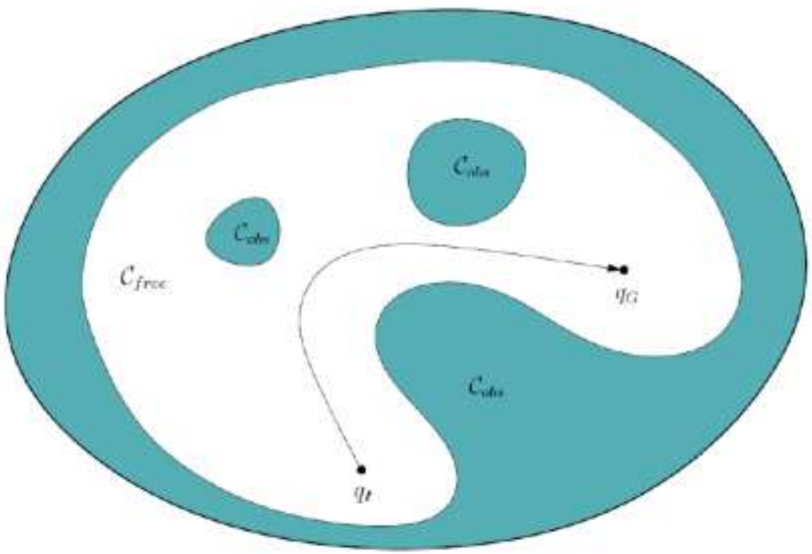


Face Detection



Path Planning

- The path planning problem involves finding how to go from one configuration to another without any collisions, while optimizing an objective function.



Courtesy: Technical University of Munich

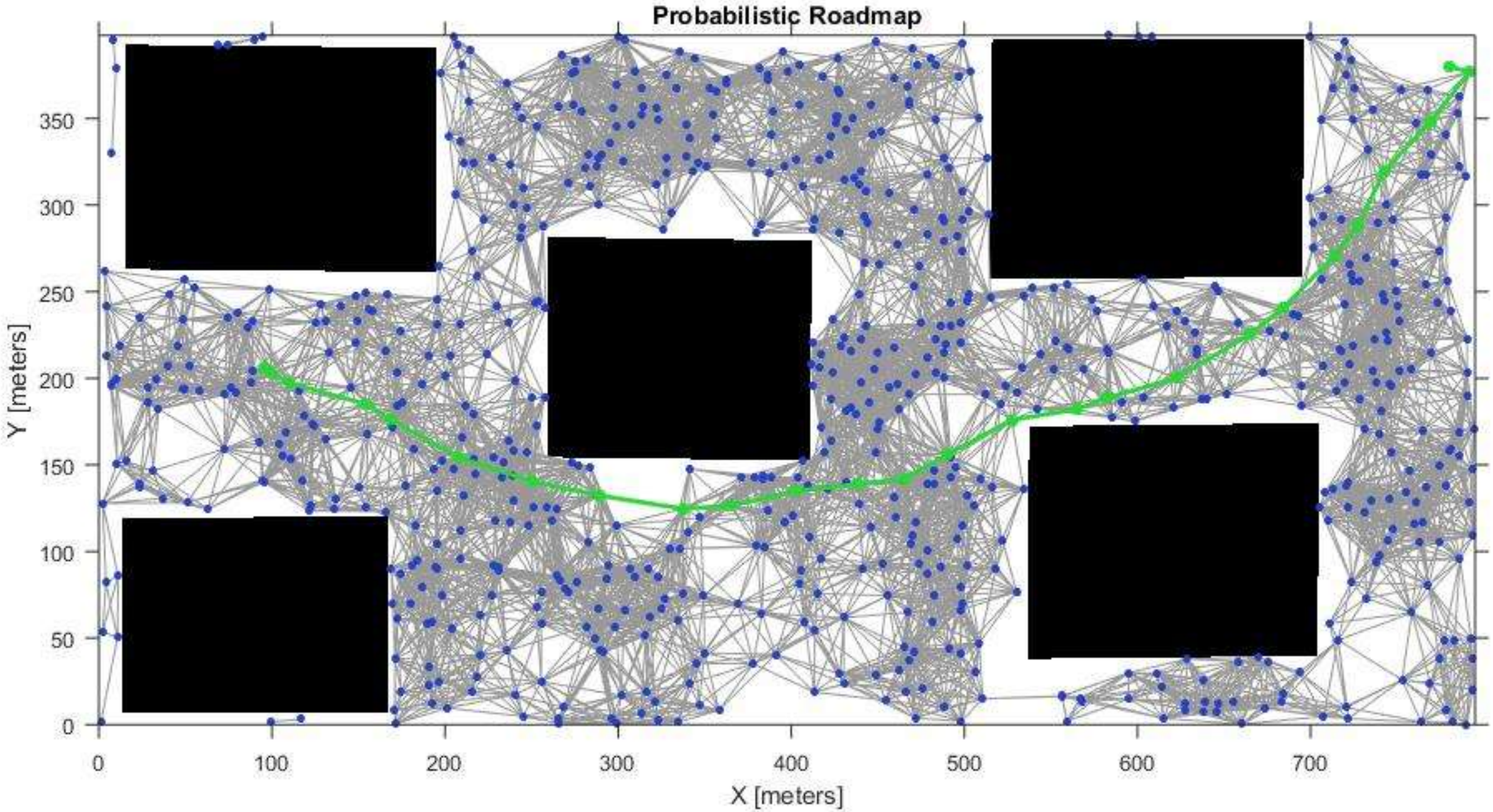
- The objective function might be based on energy consumption, speed of execution, path lengths, robustness against disturbances, etc. Hence, multiple strategies exist to solve particular motion planning problems.

Computer Vision and Path Planning algorithms

Path Planning

- One such strategy is the Probabilistic Roadmap, which is a sampling based planning algorithm in the configuration space.
- The algorithm circumvents the high running times of traditional search algorithms by randomly sampling the configuration space.
- Therefore, instead of constructing a graph with all possible nodes, the roadmap is constructed from a sample that serves as a representative.
- The traditional search algorithm is then applied over this graph, thereby increasing the speed of the entire planning process.

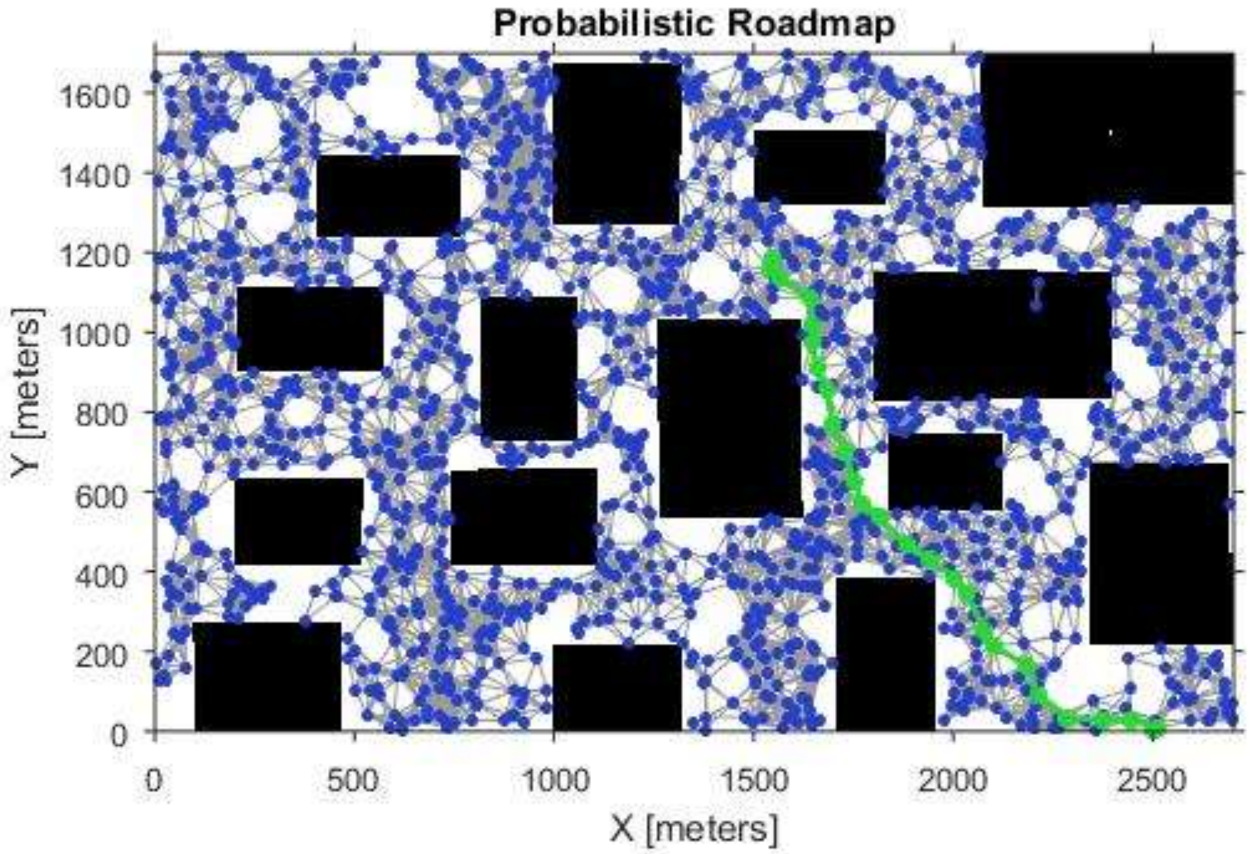
Computer Vision and Path Planning algorithms



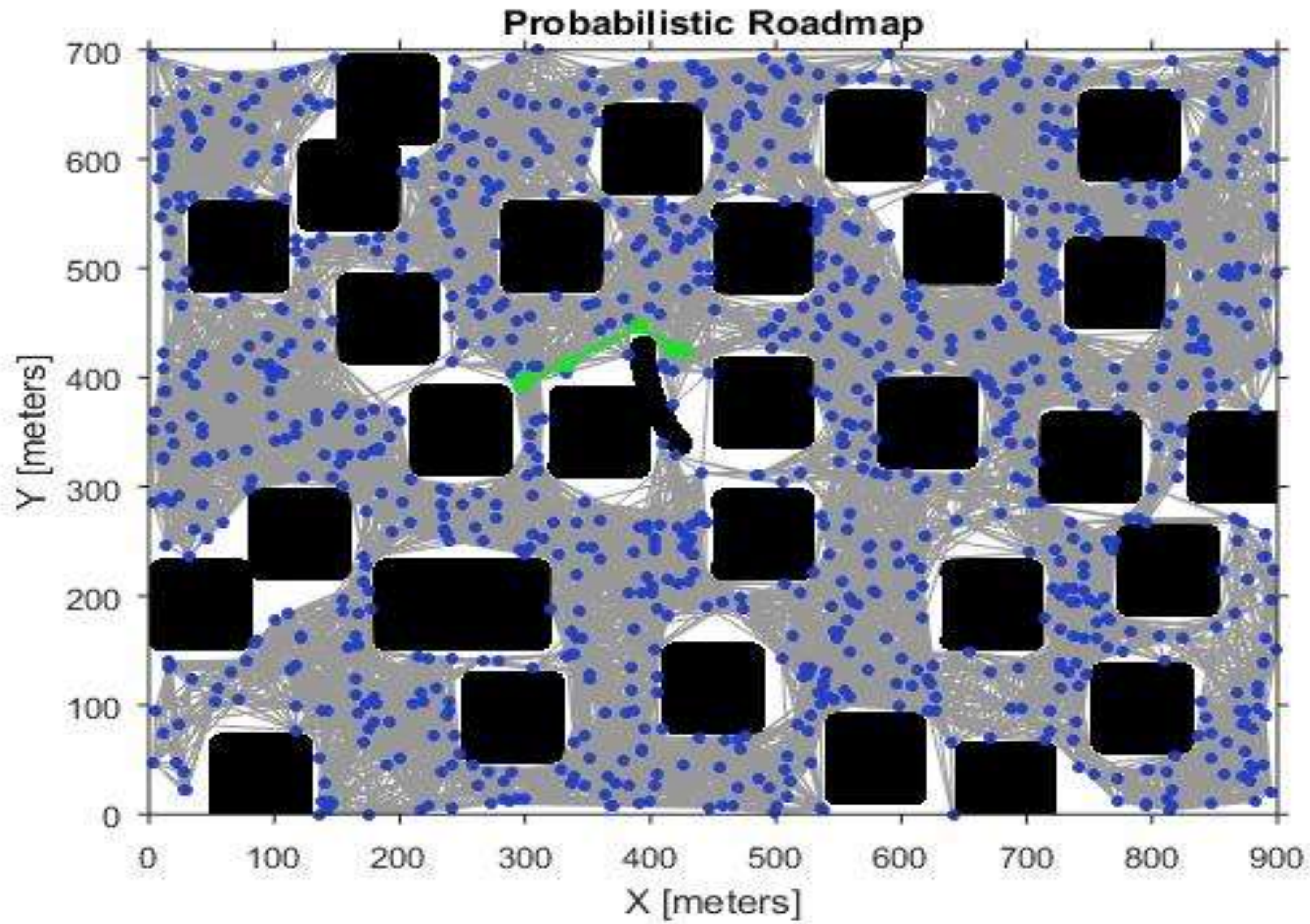
Mission planning

- We consider the problem of multiple people to save in multiple locations, which going beyond path planning, is mission planning for the ground vehicle
- Since time and resources are limited, the ground vehicle has to decide which place to visit first, and this priority is given based on a cost function that we developed.
- The cost function consists of parameters like the distance to be travelled and the number of people in each location.
- The distance is obtained from the planned path, and the number of people are obtained from the Viola Jones face detection scheme

Mission planning

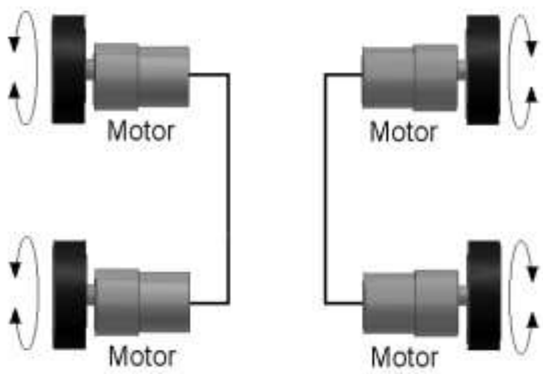


Re-planning


Probabilistic Roadmap
Y [meters]
X [meters]
0
100
200
300
400
500
600
700
800
900

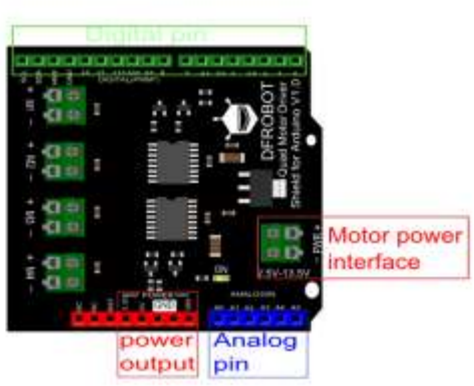
Ground Vehicle Specifications

- The ground vehicle has a 4 wheeled differential drive setup that works on an ARDUINO platform



- The differentially steered wheels are attached to motors that are powered using a Quad Motor Driver Shield.
- The driver shield can control four motors at a time.
- The Quad Motor Driver Shield has been preferred over two L298D motor drivers due to the reduction in size of the components and good heat dissipation properties owing to improved efficiency.

Ground Vehicle Specifications



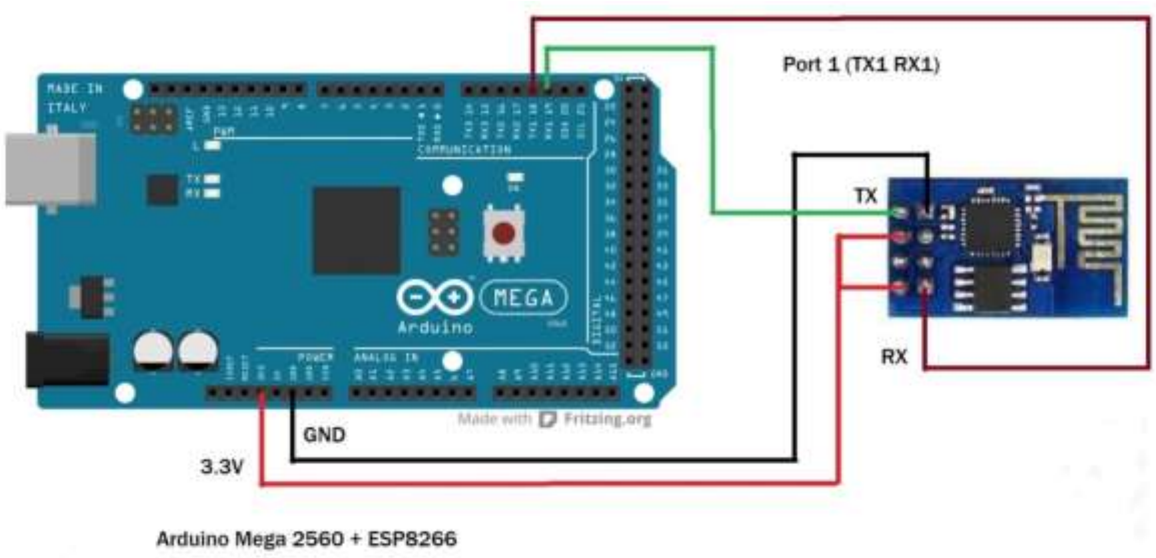
Quad Motor Driver Shield

- The drive shield with motors are connected to the digital pins 3, 4, 5, 6, 7, 8, 11 and 12 of an ARDUINO MEGA 2560 board.

Hardware connection between Quad Motor Driver Shield and MEGA 2560

WiFi MODULE

- The ground robot is equipped with the ability to transfer data wirelessly to a remote desktop (Master node) using ESP8266 WiFi module
- ESP8266 is an impressive, low cost WiFi module suitable for adding WiFi functionality to an existing microcontroller project via a UART serial connection



Hardware connection between Esp8266 and MEGA 2560

THE ThingSpeak PLATFORM

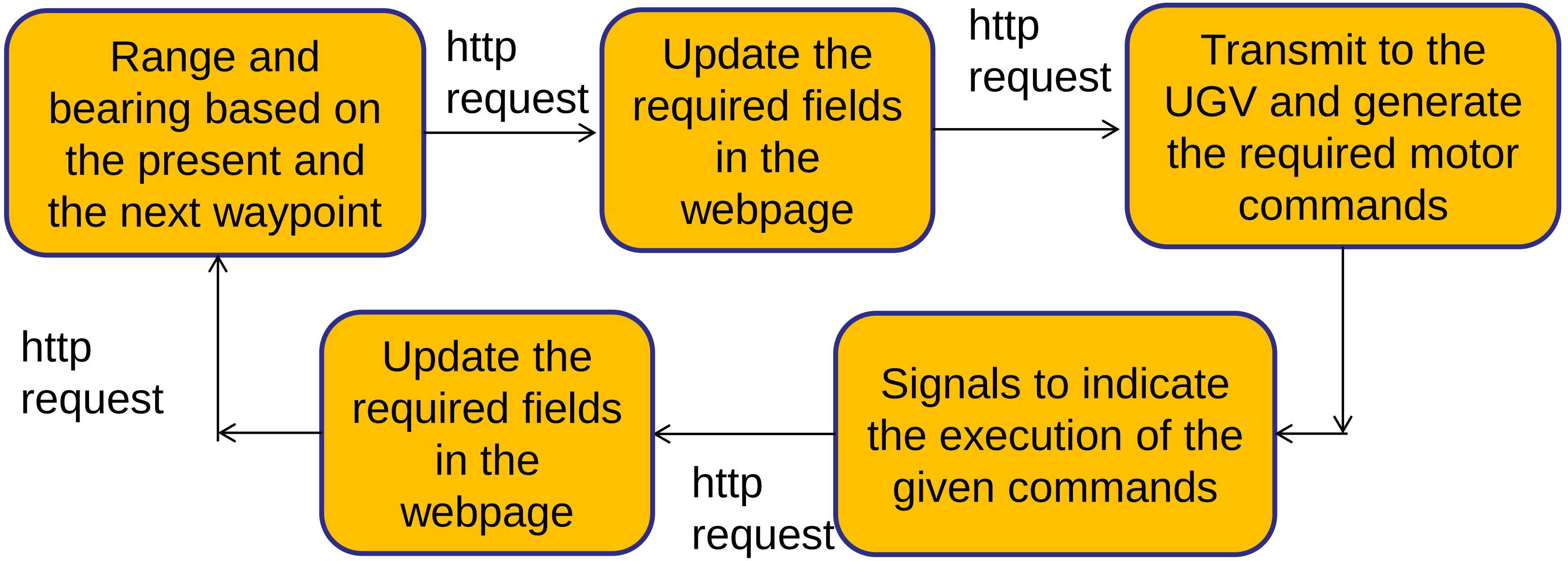
- For the ground robot to move from one location to another, motor commands are generated based on the range and bearing calculation which is performed on MATLAB in a remote desktop.
- To transfer the motor commands wirelessly to the ground robot, it is necessary to have a common platform interfaceable with both MATLAB and ARDUINO so that motor commands and acknowledgements can be sent and received using HTTP requests.
- ThingSpeak is one such platform.

Ground Vehicle Specifications

- ThingSpeak is an open source Internet of Things (IoT) platform to store and retrieve data from things using the HTTP protocol over the Internet or via a Local Area Network.

- ThingSpeak allows users to create channels with specific fields, allows them to upload/read data from specific fields of the channels using write/read keys respectively.

Ground Vehicle Specifications



Ground Vehicle Specifications

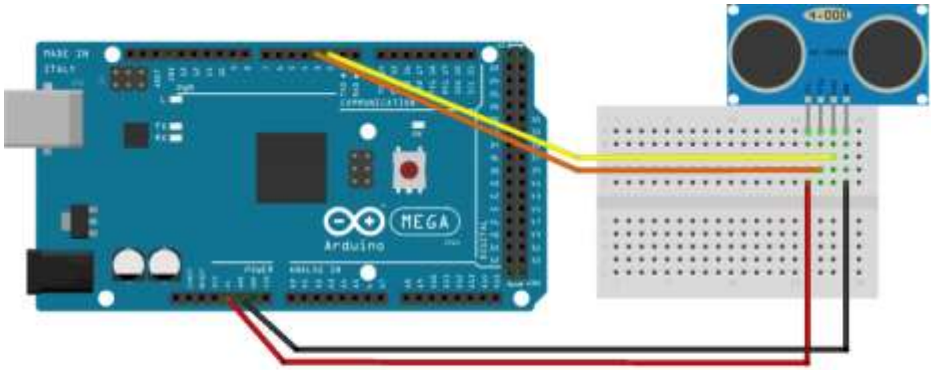
OBJECT DETECTION MODULES

- In order to detect the presence of obstacles in robot’s path, the ground robot is equipped with an ultrasonic sensor (ARDUINO interfaceable) and a camera module (RASPBERRY PI interfaceable).
- Raspberry Pi camera module V2 is an 8 MP device which can take photos and record videos.
- The image output can be obtained in the following formats: JPEG (accelerated), JPEG + RAW, GIF, BMP, PNG, YUV420, RGB888.
- The camera module requires almost 200 – 250 mA of current

Hardware connection between camera module and Rapberri Pi board

Ground Vehicle Specifications

- The Ultrasonic sensor module used is HC-SR04.
- The module provides 2cm to 40 cm non-contact measurement function, the ranging accuracy can reach to 3mm.
- The time from sending the ultrasonic pulse to receiving the echo pulse is recorded using a built in counter.
- The device can detect any object that lies within a span of 15°.
- 5V DC and 15mA current is required for the proper functioning of the device.



Hardware connection between HC SR04 and MEGA 2560

Ground Vehicle Specifications

POWER SOURCES

- The ARDUINO MEGA 2560 and the RASPBERRY PI type 3 model B are powered up using different power sources.
- In order to supply sufficient current to the two motors, WiFi module and the Ultrasonic sensor, six rechargeable AA batteries, each with 2800mAh and 1.2V are used.
- According to the specifications of the camera module, the RASPBERRY PI board is powered with a power bank that can provide 5V and 2A current.

Experimental Results

Conclusion

- This project is a simple, scaled down implementation of the collaboration between unmanned aerial and ground vehicles for search and rescue purposes, specifically, in earthquake scenarios.
- A commercial aerial vehicle was used, while the ground vehicle was custom built according to our specifications.
- A large mock disaster setup was built, with dimensions 9m x 7m
- Various standard computer vision and path planning algorithms were used to implement this collaboration on various levels.
- The mission planning and re-planning algorithms were developed on our own and implemented successfully.
- Using the hardware, combined with the software that contains the core algorithms, the objectives of this project were successfully satisfied.

Future Work

- Our solution can be developed in many possible ways.
- Replacing Radio Controlled drones with computer controlled drones will a significant improvement as it can improve the footage quality.
- By building a robust ground vehicle, built with micro controllers with better functionality than ARDUINO, can remove the necessity of a master node and provide direct communication between a UAV and a UGV.
- By the use of visual odometry, the map can be updated online which saves a lot of time.
- It is to be noted that predefined obstacles were used here. This is not the case in a real life disaster scenario. To overcome this problem, Learning techniques can be used to detect if the image contains an obstacle or not.

References

- Delmerico, J., Mueggler, E., Nitsch, J. and Scaramuzza, D., 2017. Active autonomous aerial exploration for ground robot path planning. IEEE Robotics and Automation Letters, 2(2), pp.664-671.

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