Feasibility Study

Sparse Localization for Micro-UAVs in Disaster Response

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Collaboration Commonwealth Scientific and Industrial Research Organization, Australia

Team

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  - Dr. Navinda Kottege, CSIRO, Australia (External Supervisor)

Problem Statement

- Disasters like building collapses have become a common occurrence
- Saving the lives of those who have been trapped is of utmost importance

Problem Statement Contd.

- However, it may risk the lives of those who are involved in rescue operations
- Also, usually there is a certain delay involved in conventional approaches
- There are limitations in using some of the newer methods as well
    - Eg.: GPS localization is not possible inside buildings for autonomous robots

Proposed Solution

- To introduce a system which can help during rescue operations without risking further human lives
- These tasks are intended to be done using a micro UAV which has several advantages over other methods
- Sparse sensing is to be used for localization because other conventional sensing techniques require a heavier payload. This leads to a shorter flight time, therefore reduces the effectiveness of the system

Objectives

- The autonomous vehicle should;
  - Enter and navigate through an unknown structure
  - Identify trapped people
  - Send their locations to the rescuers
- Simultaneous Localisation and Mapping (SLAM) using sparse sensing is the base of our approach
  - Localisation using sparse sensing is performed in order to navigate the UAV properly
  - A 3D sparse map should be created to help initiate the rescue operations

Scope

- Use of an UAV that is small enough to enter into most parts of the collapsed structure
- The system only intends to provide sufficient information for the rescue teams to find trapped people. It would not be capable of mapping the structure with high precision
- Due to limited processing power available, structures that present highly complex scenarios are ignored

Evaluation of Alternative Strategies
Building Collapse Rescue Methods

	Method		
	Human Rescue Teams	**Heavy Machineries**	**Robots**
Preparation time	High	High	Moderate
Danger to rescue teams	High	High	Low
Time to identify trapped people	Moderate	High	Moderate
Danger to trapped people	Low	High	Low

Evaluation of Alternative Strategies

Robot Types

Tele-operated	**Semi Autonomous**	**Fully Autonomous**
Trained operators required	Human in the loop method.	Can navigated automatically
Need to memorize the paths discovered by the robot.	Can automate the mapping process	Automatically maps the environment
Need time to perform precise maneuvers.	Automated maneuvers	Automated maneuvers
Communication link is required.	Communication link is not mandatory.	Communication link is not mandatory
Human interaction in decision making	Human interaction in decision making	Automated decision making

	Ground Robots	**Helicopter, Bicopter, Tricopter**	**Quadcopter**	**Pentacopters and above**
Speed	Low	High	High	High
Stability	High	Low	High	High
Mechanical complexity	Moderate	High	Low	Low
Ability to move to higher places	Low	High	High	High
High speed maneuvering	Not Possible	Not Possible	Possible	Possible

Evaluation of Alternative Strategies

Autonomous Quadcopter platforms

	DJI Phantom[?]	**Pixhawk[?]**	**Parrot AR drone[?]**	**CrazyFlie[?]**
				
Type	Complete system	Flight Controller only	Complete system	Complete system
Size	Medium	Vary	Medium	Very small
Access to hardware level	Not provided	Provided	Not provided	Provided
Electronic module integration	Not possible	Possible	Not possible	Possible
Cost	High	Medium	Medium	Low

[1]www.dji.com/phantom-4/info
[2]ardupilot.org/copter/docs/common-pixhawk-overview
[3]www.sciautonics.com/parrot-ar-drone-2-0-review
[4]www.bitcraze.io/crazyflie-2/

Evaluation of Alternative Strategies

Sensing methods for autonomous navigation and mapping

Vision based	**LIDAR**	**Sparse Sensing**
[1][2]	[3][4]	[5][6]
3D map	3D point cloud	Low resolution grid maps
Extract features from images	Measure distance to objects	Measure distance to objects

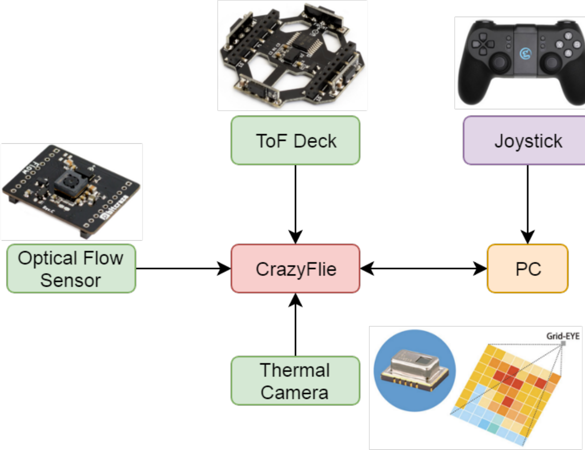
[1] C. Troiani, S. A. Zanati, and A. Martinelli, A 3 points vision based approach for mav localization in gps denied environments, in 2013 European Conference on Mobile Robots.
[2] D. Li, Q. Li, L. Tang, S. Yang, N. Cheng, and J. Song, Invariant observer-based state estimation for micro-aerial vehicles in gps-denied indoor environments using an rgb-d camera and mems inertial sensors, Micromachines, vol. 6.
[3] Lorenz Wellhausen, Renaud Dub and Abel Gawel, Reliable real-time change detection and mapping for 3D LiDARs, Safety, Security and Rescue Robotics (SSRR), 2017 IEEE International Symposium.
[4] Paulo V. K. Borges and Alberto Elfes, Real-time autonomous ground vehicle navigation in heterogeneous environments using a 3D LiDAR, Intelligent Robots and Systems (IROS), 2017 IEEE/RSJ International Conference.
[5] Kristopher R. Beevers and Wesley H. Huang An Embedded Implementation of SLAM with Sparse Sensing, Submitted the 2008 IEEE International Conference on Robotics & Automation (ICRA 2008)

[6] K. R. Beevers. Mapping with limited sensing. PhD thesis, Rensselaer Polytechnic Institute, Troy, NY, January 2007.

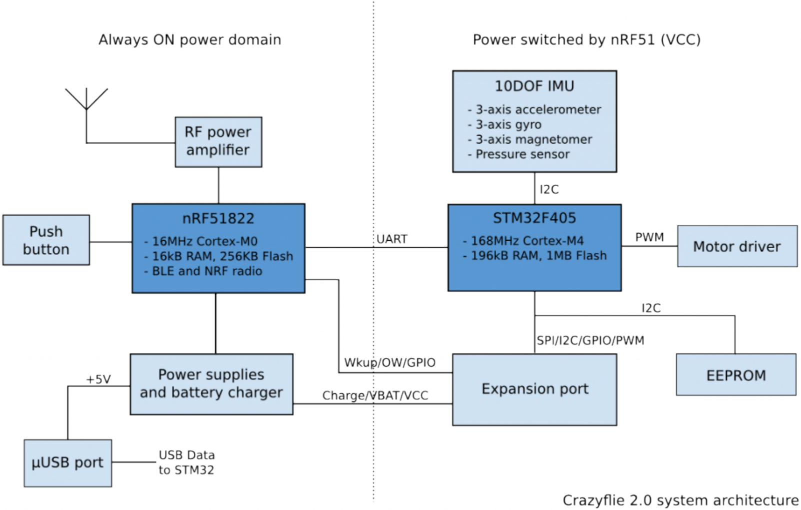
Sensing methods comparison

	Method		
	Vision based	**High resolution range sensors**	**Distance measurement sensors**
Associated hardware	Monocular/ Stereo Camera	LIDAR	**ToF** / IR / Sonar
Weight	High	High	Very Low
Size	Large	Large	Small
External lighting	Required	Not required	Not required
Computational complexity	High	High	Low
Power Consumption	High	High	Low

Project Architecture



CrazyFlie 2.0 System Architecture



Crazyflie 2.0 system architecture

Uniqueness of the Solution

- Introduce indoor micro drones for disaster management in Sri Lanka
- Use sparse sensing to build low resolution 3D indoor maps

Potential Customers

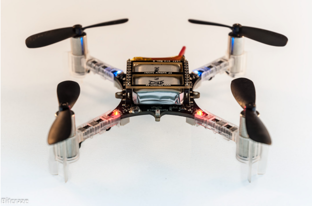
- Ministry of Disaster Management
- National Disaster Management Council
- Fire and Rescue Services

Risk factors

Category	Risk	Solution
Technical	Limited battery life	Continuous battery level monitoring; Return to start position
Technical	Deprecated motors	Buy extra motors as backup
Technical	Damages to hardware	Use of software simulation to verify algorithms and using hardware at the final phase
Technical	Environmental impacts when testing on hardware	Design and build a customizable arena in university premises
Financial	Expenses for the hardware	Partially sponsored by CSIRO

Resources

- Software Platforms
  - ROS
  - Gazebo
  - MATLAB
  - Python
  - C++
- Hardware Platform
  - CrazyFlie 2.0



Budget

Component	Price	Status
CrazyFlie 2.0	USD 180.00	Funded*
PMW3901 Optical flow sensor	USD 35.00	Funded*
Radio receiver	USD 30.00	Funded*
Range Sensor deck (Custom design)	USD 120.00	Funded*
Micro FPV camera	USD 42.00	Funded*
2.4GHz AV receiver	USD 68.00	Funded*
AMG8833 Thermal camera	USD 40.00	Not Funded
Extra motor pack	USD 20.00	Not Funded

*Funded by CSIRO, Australia.

Task Delegation

Tharindu

- Building up the mathematical model
- Working on control systems
- Simulation on hardware platform

Padmal

- ROS related programming
- Algorithm implementation
- Simulation programming

Task Delegation Contd.

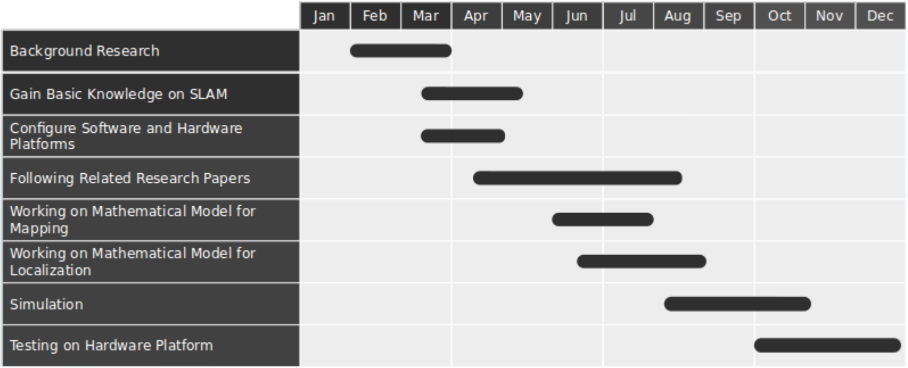
Dasun

- Setup on Hardware platform
- Simulation on hardware platform
- Simulation area management

Nadeera

- Building up the mathematical model
- ROS related programming
- Algorithm implementation

Project Timeline



Sponsership

Robotics and Automation Laboratory,
Cyber Physical Systems,
Data 61,
Commonwealth Scientific and Industrial Research Organization,
Australia.

Deliverables

1. Autonomous navigation inside an unstructured environment
   1. Obstacle avoidance
   2. Path planning
2. A Low resolution 3D map of the environment
3. Positions of the humans inside the environment. Expected to demonstrate using hot water bottles.

Current Progress

- Increase the stability of the quadcopter using the optical flow sensor
- Build the radio link with the PC to send navigation commands
- Test a state estimation algorithm including position tracking
- Track the trajectory of the quadcopter while moving