MiniMappers
Charting Hazardous Indoor Spaces using Robot Swarms

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November 8, 2017

Problem Statement / Definition

To design and develop the simulation and implementation of a multi-robot system, based on the swarm heuristic, as a scalable and robust solution to Simultaneous Localization And Mapping (SLAM) within a bounded (indoor) region, and to study its suitability and efficacy at the task at hand.

Overview

Introduction

Target Environments

What indoor regions need to be mapped?
Automated mapping is required in either vast, hard to reach or hazardous indoor environments. Such regions of interest need to be mapped before personnel or specialized equipment are deployed.

Applications

- Surveillance, e.g., search and rescue ops, urban counter-offensives.
- Exploration, e.g., mining, archeology.

Robots for Mapping

Why use Robots?
Tasks performed by automated robots strive to minimize human risk, and improve efficiency in cost and effort.

Essential Characteristics

- **Precision**, the degree of detail in the data collected,
- **Robustness**, the ability of the system to operate in the face of hazards,
- **Scalability**, the ability of the system to increase its capacity to deal with larger areas of interest.

Issues with Traditional Multi-Robot Systems

- System may not be able to cope with the failure of critical robots.
- Costs of adding additional robots increases with the complexity of its design, limiting scalability.

Moving toward Robot Swarms

What is Swarm Robotics?
Organization and operation of large groups of relatively simple robots through the use of local rules. Characterized by decentralized control, lack of synchronization, simple and (quasi) identical members.

Why Swarm Robotics?

- **Scalable**, interaction is local, individuals can join or quit the task at any time,
- **Stable**, can continue to function when a section of the swarm quits due to failure,
- **Parallel**, can deal with multiple targets/locations simulatenously,
- **Economic**, the cost of the whole system is significantly lower than a complex single robot.

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Literature Survey

Literature Survey 1

Mapping Using Vision: Trinocular stereo system mounted on a bot to generate Scale Invariant Feature Transform (SIFT) features for each image. Stereo matching matched each image with relative real world coordinates. Least Squares was used on the SIFT features to compute egomotion.

[Se, et al., 2001]

Multi-Robot SLAM without Prior Information: Successfully aggregated local maps without knowledge of robot poses and identifiable landmarks. Map representation allows constant time updates with a linear memory requirement. Algorithm features incremental and local updates.

[Thrun and Liu, 2005]

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Literature Survey 2

Heterogenous Robot System: Surveillance performed using three robot classes. Mapping robots explore the environment, build an occupancy grid and identify the object of interest. The object is monitored through strategic deployment of Sensor robots coordinated by Leader robots.

[Howard, et al., (2006)]

Mapping with Robot Swarms: Localization performed by collecting data relative to weighted landmarks. Task allocation determined through the robot's ability to move based on constraints and information quality, and the robot's desire to move based on gathered local data.

[Rothermich, et al., (2004)]

Literature Survey 3

Introductory Texts to Swarm Robotics: These texts are compilations of recent advances in the field. They highlight the key features, review the tasks, and talk about the characteristics of Swarm Robotics with emphasis on their advantages over traditional multi-robot systems.

[Navarro and Matía (2012)]
[Tan and Zheng (2013)]
[Bayındır (2016)]

Methodology

Methodology

Design and development of the project will be carried out on the Robot Operating System (ROS). The project timeline comprises of three major phases, with each phase acting as a milestone, as well as the completion of one aspect of the problem.

Phase 1: Design and Simulation
Phase 2: Data Collection, Aggregation and Rendering
Phase 3: Implementation in Hardware

Phase 1: Design and Simulation

- Simulation will be carried out on the **Player/Stage/Gazebo** stack over ROS.
- The **Information Exchange Module (IEM)** will be implemented using **Direct Broadcast Communication** over wireless Ethernet.
- A **Field Potential** heuristic will be used to control dispersion, cooperation and task allocation.
- **Microscopic Modelling:** Individual robots move towards the point of lowest potential.
- **Macroscopic modelling:** Robots must not stray or get trapped in place.

Phase 2: Data Collection, Aggregation and Rendering

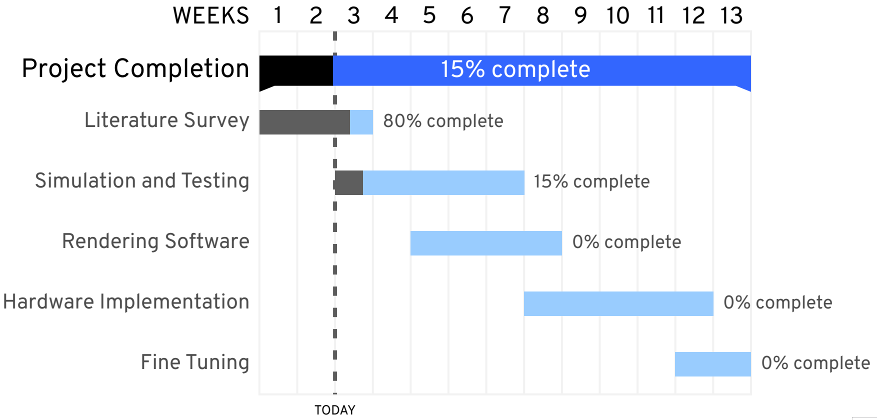
- The **Data Collection Module (DCM)** will be implemented using **Ult**rasonic, **IM**U, **A**udio and **Te**mperature sensors (nicknamed **Ultimate**).
- **Ultrasonic** sensor for obstacle distance approximations.
- **Inertial Measurement Unit (IMU)** to gather data on the surface traversed.
- **Audio** and **Temperature** are secondary percepts to aid surveillance.
- Aggregation of locally gathered data occurs offline and an appropriate representation of the map is generated.
- The map will be rendered with cues for temperature and sounds to highlight critical regions.

Phase 3: Implementation in Hardware

- Selecting an appropriate microcontroller along with sensors of appropriate quality and price.
- Creating a dynamically changing environment with appropriate tests for each aspect.
- Tweaking hardware to ensure consistent performance.

Timeline (Gantt Chart)

Timeline for Project Completion (Gantt Chart) Nov 2017–10th April 2018



Expected Outcome

Expected Outcome/ Results

1. Simulation of Swarm Behaviour

To develop an understanding of the emergent behaviour of a robot swarm in a simulated environment.

2. Test and Verify Swarm Algorithms

A set of implemented, tested and verified algorithms for coordinating robot swarms. These algorithms will target dispersion, localization, task allocation and aggregation of local data.

3. Implementation in Hardware

A functional robot swarm solution to SLAM.

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