MiniMappers
Charting Hazardous Indoor Spaces using Robot Swarms

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Overview

Problem Statement / Definition

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

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 optimize 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 simultaneously,
- **Economic**, the cost of the whole system is significantly lower than a complex single robot.

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]

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: Outline

The project time line will comprise of three major phases, where each phase acts as a milestone, as well as the completion of one aspect of the problem statement.

Phase 1: Design and Simulation of the Swarm Structure
Phase 2: Data Collection Modules and Rendering Software
Phase 3: Translation to Hardware

Methodology: Phase 1

Design and Simulation of the Swarm

Goals

- Designing the architecture of the Robot Swarm.
- Develop algorithms for higher level coordination mechanisms.
- Pick suitable protocols for implementing communication methods.
- Simulate and verify the selected algorithms on a software testbed.

Status

- Each robot is modeled with four fixed wheels, a SONAR and a wireless transceiver.
  - All four wheels are powered.
  - The SONAR is modeled as an arc of rays. Sensor reading is the minimum distance detected.

Methodology: Phase 1

Design and Simulation of the Swarm

Status

- Although homogeneous robots, tasks are not distributed uniformly.
  - **Fixed robots** act as fixed localization points to provide a frame of reference. Also coordinate communication.
  - **Roaming robots** traverse the region to build a map.
- Communication only between roaming robot and fixed robot. Message is a ping of the current location relative to the fixed robot.
- Each robot estimates a potential at its current location by considering
  - its SONAR reading,
  - its distance from fixed robots,
  - the extent of unexplored region,
  - the response from fixed robots.

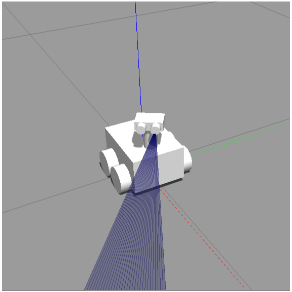
Methodology: Phase 1

Design and Simulation of the Swarm

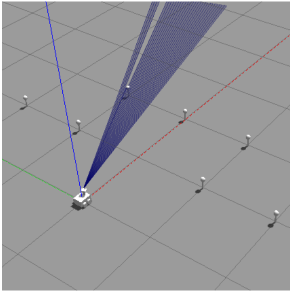
Status

- Potential used to update current velocity.
- This is being tested by replacing the unexplored region with a destination. The frame of reference is provided by the simulator directly instead of using fixed robots.

Design and Simulation of the Swarm



(a) MiniMapper Model



(b) SONAR Ranging

Figure: Simulating the Robot

Data Collection Modules and Rendering Software

Goals

- Decide the type and quantity of sensors and data transmitters.
- Design the protocol to transfer data to the external processing unit.
- Develop the internal representation of the map data.
- Develop the algorithm to aggregate local maps into the complete representation.
- Using suitable libraries, build the map rendering software.
- Test these algorithms in a procedurally generated simulated environment.

Methodology: Phase 2

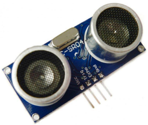
Data Collection Modules and Rendering Software

Status

- The following sensors have been considered,
  - HCSR04 Ultrasonic Module for the SONAR.
  - MPU6050 IMU
  - TMP06 IR Temperature Sensor
  - Electret Sound Detector
  - GP2Y0A41SK0F Sharp IR sensor. Low range to compliment HCSR04.
- ESP8266 WiFi module will be used for communication.
- Google's Protocol Buffers will be used to structure the data format between the swarm and any external processing system.

Methodology: Phase 2

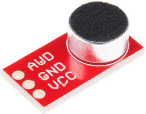
Data Collection Modules and Rendering Software



(a) HCSR04 Ultrasonic

(b) GP2Y0A41SK0F Sharp IR

(c) TMP006 IR Temperature



(d) Electret Sound Detector

Figure: Sensors

Data Collection Modules and Rendering Software

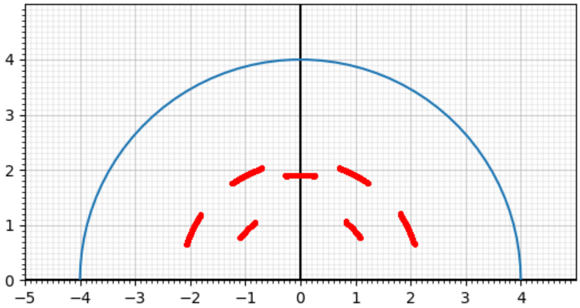


Figure: SONAR Plot

Translation to Hardware

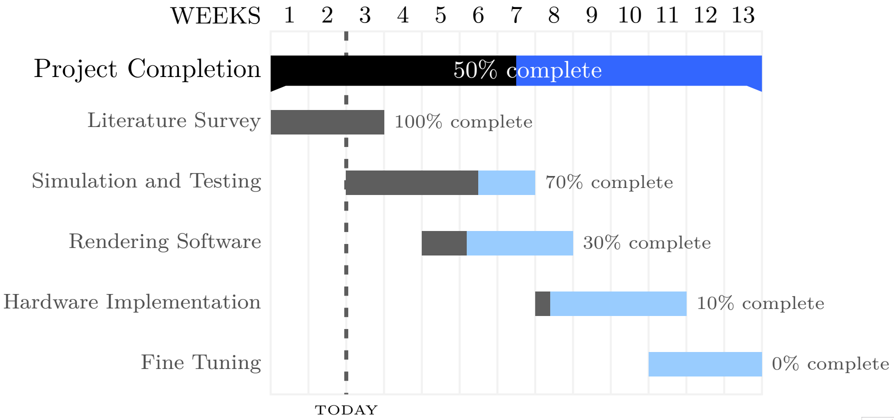
Goals

- Implement the robots in hardware and load the software modules.
- Build a re-organizable environment using relocatable objects.
- Test the robot swarm in the environment.

Status

- Work on the software modules for controlling sensors is underway. The control software is split into two modules,
  - Human detection module to read the TMP06 IR sensor and Electret Sound detector to estimate human presence in a region.
  - Ranging module to read the Ultrasonic sensor, the IMU and the sharp IR ranging sensor.

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



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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