Multi Robot Navigation and Mapping for Combat Environment

Functional Requirements List and Performance Specification

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Introduction

The Multi Robot Navigation and Mapping for Combat Environment project will safely enable a robot to navigate through an indoor or outdoor (urban) combat environment. The idea behind this project is that a relatively inexpensive/expendable robot would first scan an unknown area and relay a map of the area back to central command. Central command would then use that map for safe navigation of a more expensive/comprehensive robot. The overall goal of this project is to guide autonomous supply caravans or troops safely through a combat zone.

The robots that will be used for this project are the Pioneer 3D-X series robots. The 3D-X model has 8 sonar sensors in the front and sides that can get readings from + 90 degrees to -90 degrees. It has two wheels up front that allow the robot to move in any direction and an additional wheel in the back for stability. The first robot will be in charge of mapping the environment and designating a safe route that can be navigated by a second robot while avoiding any obstacles or dangers. The second robot will then use the map generated by the first robot and use a path finding algorithm to determine the best path through the environment that avoids all obstacles and threats.

Current Project Goals
- Robot Navigating
  - Find and travel to closest wall/object
  - Position robot in a specific position to wall(s)/object(s)
  - Left/right wall following
  - Determine if sensors more accurate than sonar sensors will be necessary. If so, integrate the sensors into ARIA if possible.
  - Identify appropriate sensors for combat-like environment.
  - Acquire and integrate sensors for simulated combat-alike environment (metal detector?)
  - Develop communication framework, allowing server/central command to override local control algorithms and remote control robot
- Environment Mapping
  - Research and develop algorithms to map an unknown environment
  - Research available ARIA or Pioneer robot compatible software for mapping
  - Develop framework to contribute maps to server/central command and update maps from the server
  - Research and develop algorithms to locate robot by matching its current map with the global map available on the server/central command
- Other Tasks
  - Create digital maps of the real-life-alike environments for computer simulation
  - Setup the infrastructure server for multiple robot cooperation/coordination
  - Weekly website update of project progress

High Level System Block Diagram

The high level system block diagram in Figure 1 is divided into two modes with each mode being designated a robot that is interchangeable with the other. Each robot is connected to a laptop via a USB port. The laptop runs the actual C++ program (created in Visual Studio) that will control the robot. A program called ARIA then interfaces the C++ program with the robot. Mode 1 is responsible for mapping the unknown/combat environment and relaying that map to the server via a laptop with a wireless network connection. Mode 2 is responsible for retrieving the map through a wireless laptop connection, and safely navigating through the environment. Another PC is connected to the server in case manual override would ever be required. Additional sensors (IR and metal detection) will be added later and connected directly to the ARIA program.
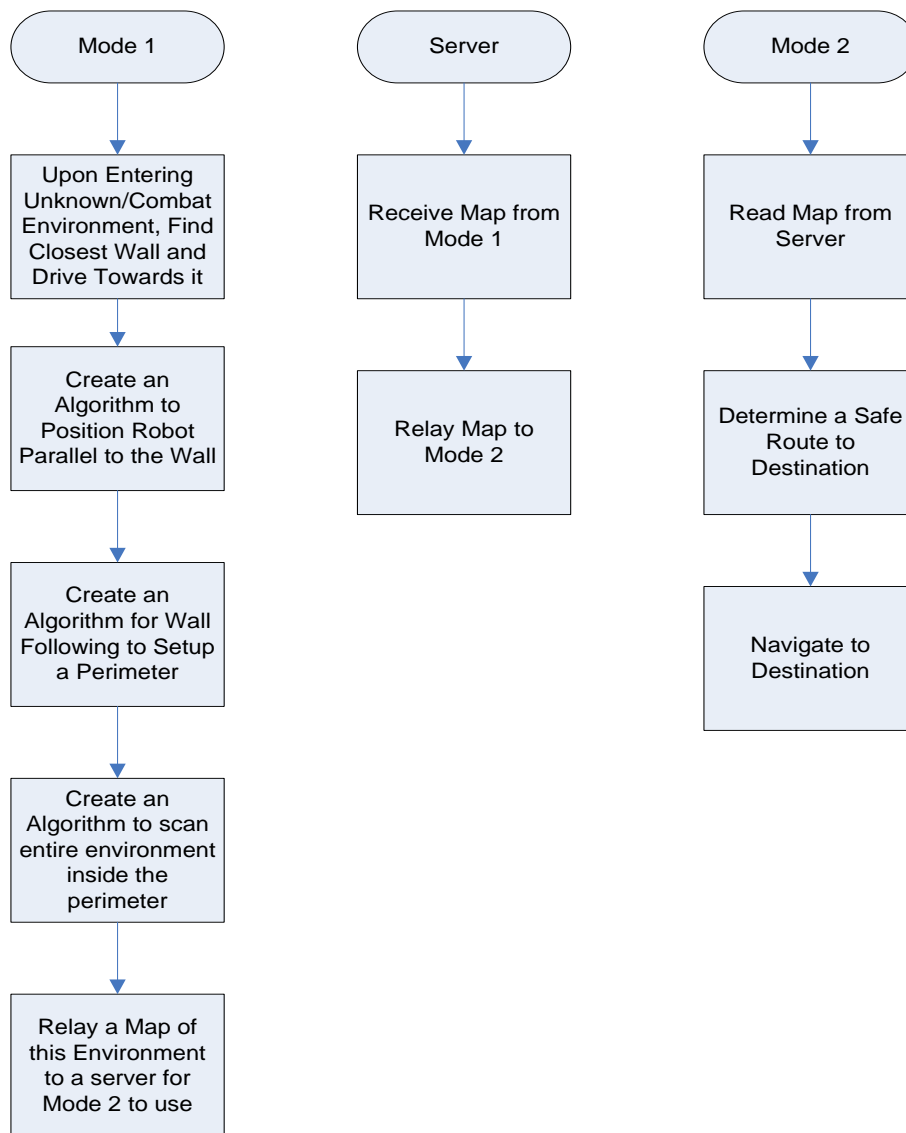
Figure 1: High Level System Block Diagram
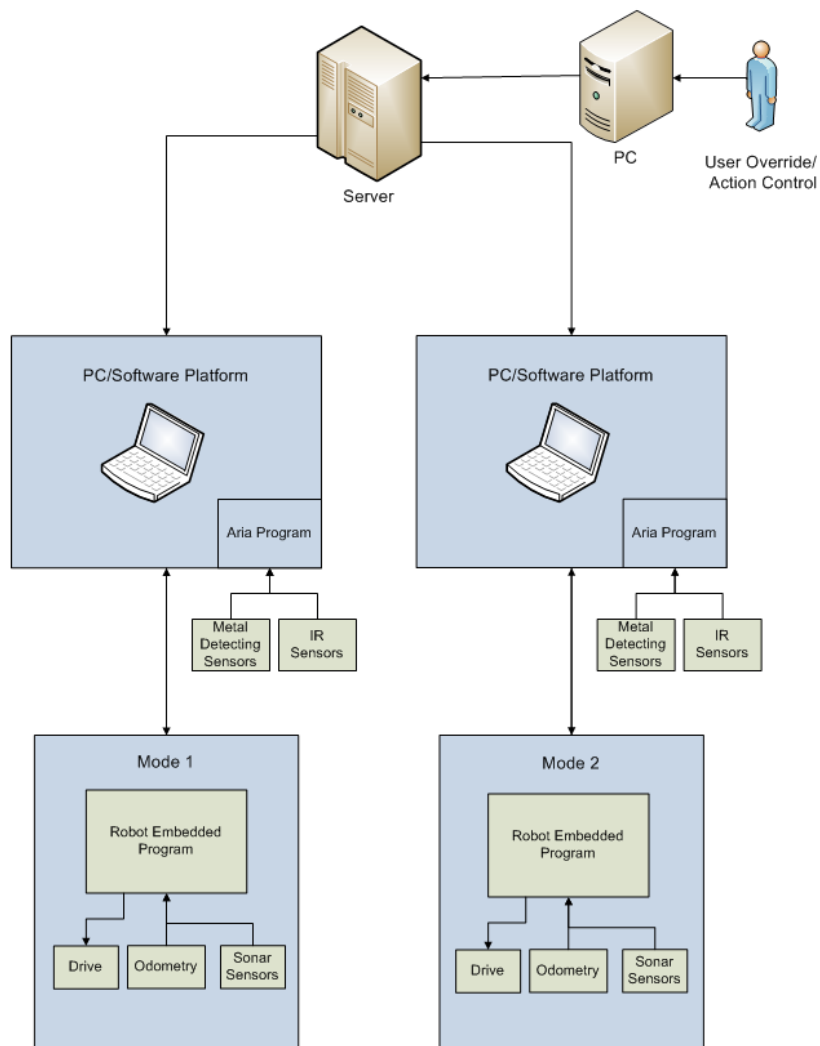
Functional Description

The high level system block diagram is divided into three main subsystems: mode 1, server, and mode 2. The first subsystem is the mode 1 subsystem. This subsystem's prime responsibility is to map an unknown/combat environment and send the map to a central server for storage. The second subsystem is the server subsystem which receives and stores the map from mode 1. When the map is completed, the server then sends that information to mode 2. The last subsystem is the mode 2 subsystem, which reads the map sent from the server. Based on the map received, mode 2 determines a safe route to the destination and then navigates through the environment. These three subsystems are all explained in better detail in Figure 2.

Figure 2: Subsystem Block Diagrams

Mode 1	Server	Mode 2
Upon Entering Unknown/Combat Environment, Find Closest Wall and Drive Towards it	Receive Map from Mode 1	Read Map from Server
Create an Algorithm to Position Robot Parallel to the Wall	Relay Map to Mode 2	Determine a Safe Route to Destination
Create an Algorithm for Wall Following to Setup a Perimeter		Navigate to Destination
Create an Algorithm to scan entire environment inside the perimeter		
Relay a Map of this Environment to a server for Mode 2 to use		

Functional Requirements

Below are the functional requirements identified for the Multi Robot Navigation and Mapping for Combat Environment project. The quantitative values of the requirements are subject to change through experimentation and research.

Navigation Requirements:

- The Pioneer shall maintain a minimum distance of 250 millimeters from its edge to all walls/obstacles. This will allow for safe navigation throughout the environments in which the Pioneer 3-DX will be used.

- The robot shall be able to navigate through the space of a standard hall doorway (810 millimeters in the US).

- The speed of the robot shall not go above 300 millimeters per second to ensure accurate sensor readings and mapping.

- The software shall localize itself on a grid of 0.3 m x 0.3 m squares. This is slightly larger than the robot (0.22 x 0.38 m) and provides enough resolution when making a map.

- Infrared lasers shall be implemented if the sonar sensors do not provide enough accurate readings for proper navigation and mapping.

- A metal detector accuracy specification will be determined via research of different sensors. Tradeoffs between cost and accuracy will influence which sensors are used.

- The robot using mode 1 shall detect any metallic substance at least 76.2 meters (3 inches) from its surface. For this project, the metal would represent some type of threat such as mines.

- The robot's path finding technique (mode 2) shall find the shortest route possible while avoiding all obstacles and potential threats.

Server/Wi-Fi Requirements

The robots must maintain a constant connection with the server to store and receive the map file using 802.11g wireless. In an actual battlefield, peer-to-peer with re-broadcasting, or deployed access points and robots with external Wi-Fi antennas would be used with encrypted transmission. Our method will be more of a proof of concept rather than a battlefield simulation.

References

[1] Nourbakhsh, Illah R., and Roland Siegwart. Introduction to Autonomous Mobile Robots (Intelligent Robotics and Autonomous Agents.) London: The MIT Press, 2004.