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February, 16, 1999

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Re: ENSC 370 Project Gerbil Functional Specifications

Dr. Andrew Rawicz,

The attached document, *Project Gerbil Functional Specifications,* outlines the proposed functionality for our project. The Gerbil's core purpose is to autonomously navigate and map a room, utilizing a positioning and sensory system. This project would allow for various applications. One such application would be the cleaning of hospital floors, which is the purpose we will explore.

Contained in this document is the proposed system functionality, as well as the specifications of the various system components. These components include the positioning and sensory systems, the system processing, and physical requirements.

TRAC Technologies comprises of four intelligent, hard-working, and innovative third-year-engineering students -- Celina Tinio, Robbie Grue, Andrew McPherson, and Travis Hammond. If you have any questions or concerns regarding our functional specification, please contact Celina Tinio at 872-3750, or by e-mail at mtinio@sfu.ca.

Sincerely,

Celina Tinio
TRAC Technology

Enclosure: *Project Gerbil Functional Specifications*

Project Gerbil Functional Specifications

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Executive Summary

The ability of machines to interact with their environments in a similar fashion to humans is of immeasurable value in today's ever-changing society. Our project, the Gerbil, is an attempt to design a small robot that will have the ability to navigate around an area, detect any objects it encounters, and maintain a current map of these objects. Among many other things, such a robot will allow areas such as hospitals to be cleaned of biohazards and other wastes which could pose health risks to human counterparts.

The Gerbil will navigate using a positioning and object sensory system, whose output signals will be manipulated by a microprocessor. The processor will then be responsible for directing the robot's movements and creating and updating the map of the area as needed.

This document describes the proposed functionality for the Gerbil project, along with some of the design choices being presented to us in regards to the positioning and sensory systems.

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Introduction

One of the inexplicable obsessions in the history of robotics is the desire to replicate the functionality of the human. Humans have many aspects which designers have found very difficult to duplicate in the realm of machines. Certain aspects, such as object recognition and navigation, have an incredible potential when combined with those advantages which a machine has over a human.

One example of this is in the area of biohazardous waste disposal. Such substances pose a substantial threat to those people who must clean them, while they have little or no effect on a machine. Therefore, a machine would be better suited to the handling of such tasks, and would be ideal if the recognition and navigation aspects of a human could be combined with its resistance to disease. This is what the Gerbil project attempts to achieve.

The purpose of this document is to describe the required functionality for the Gerbil. The intended audience for this document is Dr. Andrew Rawicz, Mr. Steve Whitmore, TRAC Technology product designers, and external design consultants.

System Overview

The Gerbil will utilize a sensory system to detect objects, and, in coordination with a positioning system, create a map of the area that it has cleaned. Once the cleaning is completed, the robot will return to its original position. This is illustrated in Figure 1 below.

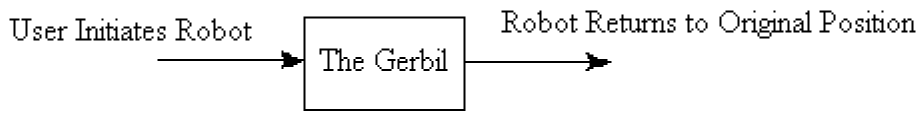

Figure 1: System Context Diagram

The Gerbil's system block diagram is show below in Figure 2. The Gerbil will have two inputs, one which is received from the surrounding objects, and another which will come from the positioning system. These signals will be manipulated by the system processing, which will in turn guide the robot's movement and maintain the map of the area.

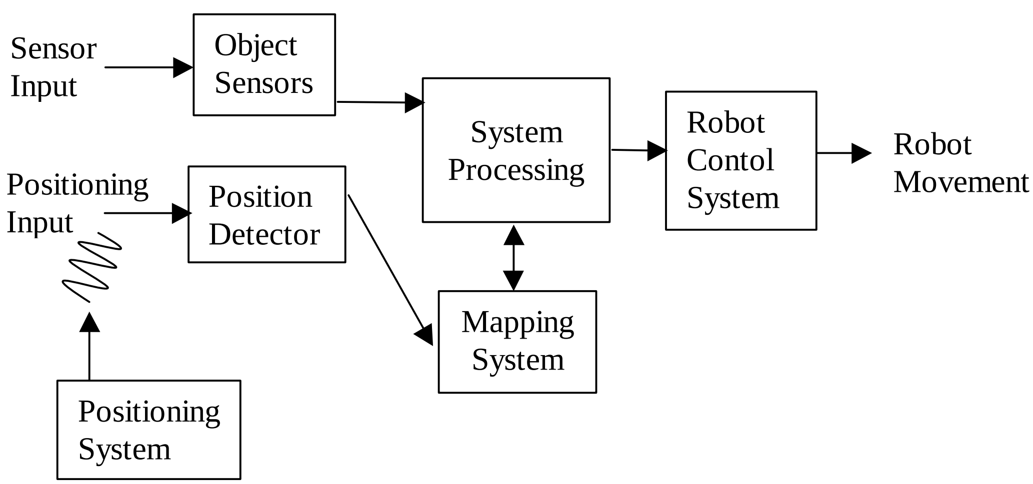

Figure 2: System Overview

This block diagram will result in the following functionality:

- Use a sensory system to sense objects within close proximity
- Use a positioning system to determine position of robot and obstacles.
- Maintain a current map of cleaned area, including any obstacles encountered
- Have ability to download map onto a computer
- Have self contained power supply
- Will perform task autonomously after user switches it on
- Will recognize completion of the task and return to original position

Positioning System

In order to map the area it is cleaning effectively, the Gerbil will require the ability to determine its position in this area. The positioning system must satisfy certain requirements in order for it to be useful, such as:

- position must be independent of the shape of the room or any obstacles
- error must be kept to a minimum to avoid mistakes in object location
- position must be continuously updated
- cost must be kept with reasonable level relative to project as a whole

Background

There are many different possible choices for the positioning system. Few of them, however, can satisfy all the criteria. Some examples are:

- **Tracking of distances traveled and turns made**. This method is very inaccurate, as with every turn made, the error is compounded. It would not be long before the data produced by such a system would be completely useless.
- **Visual detection through video equipment**. This method would not be independent of the obstacles in the area, due to the fact that the system would need to be able to distinguish between the robot and the obstacles. It would also be unable to detect the robot should an obstacle come between the path of the camera and robot.
- **Global Positioning System (GPS)**. This method is not very cost effective, and the accuracy of GPS is only within approximately a metre, which is too great an error for this application.
- **Beacon System**. This method is possibly the best method available, but would require that the robot be aware of the relative positions of the beacons, meaning they would have to be preplaced.

The Gerbil System will employ a beaconing System as described in example 4 from above. The choice has been made now because it affects functionality, as it requires the preplacing of beacons.

Positioning System Functionality

The positioning System will be comprised of a number of beacons together with a receiver onboard the robot. The System of beacons will send signals to the robot's position detector. The position detector will then decode and analyze these signals to create an internal representation of the robots position. This position will then be communicated to the System Processor. Figure 3 describes the functionality of the positioning system.

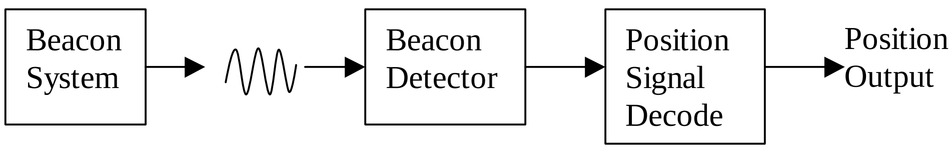

Figure 3: Positiong System Diagram

The Function of the Positioning System is as Follows.

- **Detect a signal from a number of pre-placed beacons**. The beacons need to remain in a permanent position. They should be distributed about a broad area in the room and not in a small cluster.
- **Decode the detected signals**. The Signals received by the Beacon System will be decoded and converted to a usable form.
- **Communicate the position to the System Processor**. The position information will be sent to the system processor in a usable form.

Sensory System

The positioning system will allow the Gerbil to navigate effectively within the room, however, it must still have some means of detecting any objects it may encounter. Figure 4 below gives an example of this.

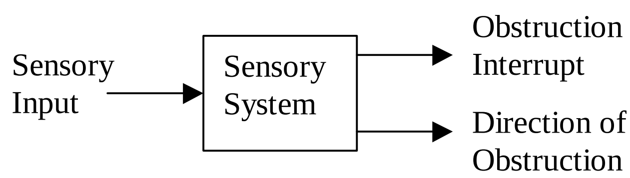

Figure 4: Object Sensors

The Sensory System shall function as follows:

- **Sense if an object is within close proximity to the robot**. Close proximity is defined as between 0 to 5 cm from the robot.
- **Communicate to the System Processor that an obstruction is near**. This communication will take the form of a flag. The Flag will tell the System Processor that there is an object within close proximity or that no objects are close to the robot.
- **Communicate to the System Processor the Direction in which the Obstruction lies**. The Sensory System will be able to determine the position of the obstruction relative to the direction in which the robot is currently oriented.

System Processor

The System Processor is the Brain of the Gerbil. It takes inputs from the position detector, the sensory system and the mapping system. Based on these inputs it outputs commands to the robot control system. It also relays information from the position and object sensory systems to the mapping system. This is illustrated bellow in Figure 5.

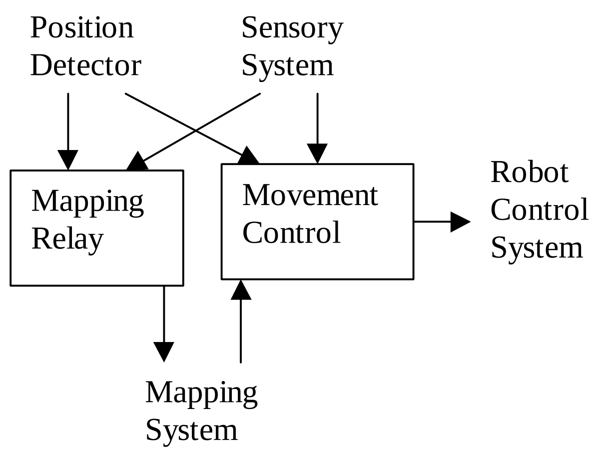

Figure 5: System Processor Block Diagram

The functions of the System Processor are as follows:

- **Relay the position and sensory information to the Mapping System**. The mapping System requires information from the sensory and positioning system. The System Processor will relay this information to the mapping system.
- **Controls the movement of the robot**. By analyzing the inputs from the Sensory system, Positioning System and the Mapping System, the System Processor will administer the appropriate movement commands to the Robot Control System.

Mapping System

The mapping system will record and maintain a map of the current environment. It has an input/output connection to the System Processor. The System processor will communicate mapping information to the mapping system and the mapping system will store the mapping information in the most efficient manner possible. The mapping system will also communicate any information about the current map when requested by the System Processor. Figure 6 shows a block diagram of the Mapping System.

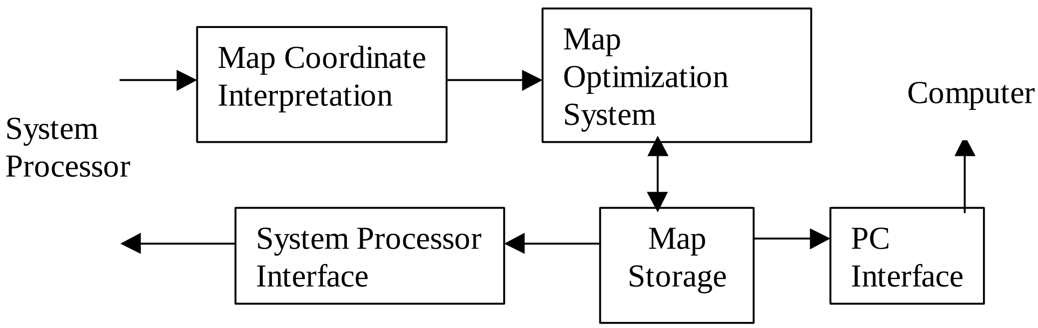

Figure 6: Mapping System

Once the signals from the positioning system and the sensory system have been sent to the system processing, the Gerbil will these signals to maintain its map of the area. The basic requirements for the Mapping System are as follows:

- **Receive Coordinates from System Processor**. The Coordinates will be interpreted and stored. The way in which they will be stored will be optimized by a map optimization system. Included in the information received by the Mapping System will be location of objects encountered, which will also be stored in memory.
- **Output Map Information to System Processor**. The system processor needs the Map information and will be allowed random access to the current map of the environment.
- **Allow downloading of map to a computer**. The System will have an interface compatible with a PC that will allow the download of the map information.

Robot Control System

One of the vital functions to the Gerbil will of course be its ability to move. The Gerbil must be able to easily negotiate its way around any obstacles that it may encounter, and its movements must be able to be controlled by the system processing. Figure 7 below gives the block diagram for the robot control system.

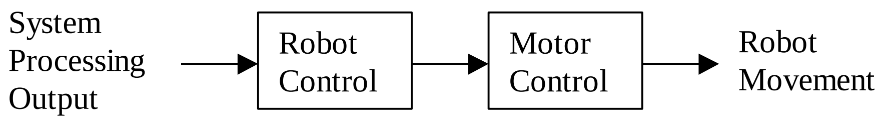

Figure 7: Robot Control Block Diagram

The control system will use the system processing to interpret the signals coming from the sensory and positioning systems, and the system processing will determine the next course of action, for example, moving left or right, backwards or forwards. The system processing will then send its command to the control system, which will instruct which motors are to be activated in order to move the robot.

The robot control system will fulfill the following functional requirements:

- **Accept Control Commands from the System Processor**. The system processor will administer commands to the Robot Control System. These commands will be executed without delay
- **Move in both a forwards and backwards direction**. The robot control system will be able to control the motors in a way such that the robot moves forward and backward in a straight line.
- **Rotate without changing position**. The robot control system will be able to control the motors in a way that will result in the robot rotating without changing position.

Physical Requirements

The Gerbil's enclosure will be rigid and portable. In addition, due to the nature of the purpose, it must also be easily cleaned and adhere to the size and weight requirements stated below in Table 1.

Table 1: Gerbil System Physical Requirements

Height	30 cm maximum
Length	50 cm maximum
Width	50 cm maximum
Weight	10 kg maximum

Environmental Requirements

The Gerbil system will conform to the following environmental requirements.

Table 2 : Gerbil System Environmental Requirements

Operating Temperature	-20°C - 60°C
Shipping Temperature	-30°C - 70°C
Heat Dissipation	Minimal

Electrical Requirements

The Gerbil system will meet the following electrical requirements.

Table 3 : Gerbil System Electrical Requirements

Voltage	15 V maximum
Power	5 Watts maximum

Safety Requirements

The Gerbil system will meet the following safety requirements.

Enclosure

The enclosure will have no sharp corners, edges, or points that would pose a danger to the user.

Electrical Isolation

All inputs and outputs, including object sensors, will be shielded and protected from external static voltage sources.

Object Avoidance

The robot will avoid collisions with objects wherever possible, therefore minimizing danger to small children and animals.

Emissions

The system shall not emit any form of combustible fuels, relying solely on the battery power.

Reliability Requirements

The Gerbil system will meet the following reliability requirements.

Accuracy

The robot will be able to follow with 5° from a parallel wall. As well, roughly 80-90% of the floor will be covered during the cleaning process.

Durability

The system will be able to withstand the frame vibrations and be robust enough for at least 2 years of daily use. As well, the robot will be able to withstand a drop from 1 meter.

Training

The user and map programmer will require a small amount of training in using the robot. A simple manual will be written for this purpose. The transmitting of data between the onboard memory and a computer will also have to be included in the manual. To further clarify the required procedures, example tests will be provided.

Potential System Limitations

The Gerbil system may be limited by the following factors:

- May be unable to clean inside of corners.
- May be unable to clean underneath objects due to height considerations.
- Will have to be manually cleaned.

Note that these limitations can be corrected upon further development on the Gerbil project and can be considered temporary.

Conclusion

The document has discussed the functional considerations of building an autonomous area mapping robot. The Gerbil project will be designed and constructed based upon the functional requirements specified here. By creating a device which fulfills these considerations, we hope to successfully created a machine which will improve the safety of handling biohazardous material, and maintain an adaptability to the numerous different applications that such a project could have.