ENG405: Design Project

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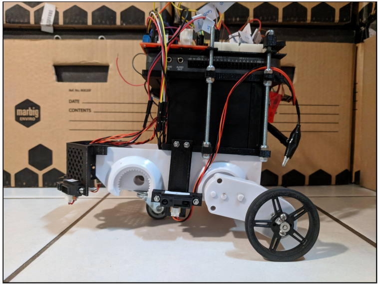
Design Criteria

Requirement Number	Description	Requirement Number	Description
R1	The robot must act autonomously	R6	The robot needs to stop on top of the finish zone or within 100mm from the zone
R2	The robot is designed to act in a 3m $\times$ 6m environment	R7	The robot must stop when it has reached the exit zone
R3	The robot can avoid obstacles of minimum size 55mm $\times$ 210mm $\times$ 297mm	R8	The robot must signal once it has reached the exit zone
R4	The robot can identify and navigate to an exit zone, demarcated by a red square of size 420mm $\times$ 297mm	R9	The robot chassis must use a Pololu Dagu Rover 5, two motor, tracked chassis with encoders (see Figure 1)
R5	The robot must move from start to finish within 3 minutes	R10	The robot must use an NI myRio 1900 powered by the Xilinx ZYNQ 7Z2010 (see Figure 2), or an Arduino powered by the ATmega328 for the embedded system.

Hardware: What does the robot's body look like?

Differential drive robot was configured using:

- two independently driven rear wheels; and
- one unpowered omidirectional wheel in the front



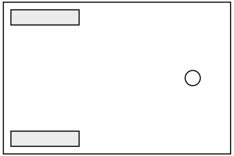


Figure: Geometrical arrangement shows two standard wheels, each driven by a separate motor, in a differential drive configuration. A passive omnidirectional wheel is mounted at the opposite end of the chassis.

Two main devices used to sense the environment in the field of mobile robotics:

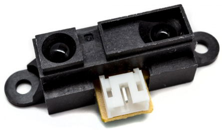


Figure: One-dimensional Infra-red ranging sensor

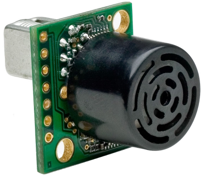


Figure: Ultrasonic time of flight ranging sensor

Hardware: How does the robot sense the world?

The two main sensors for obtaining odometry (i.e. the robot tracking it's position) are:

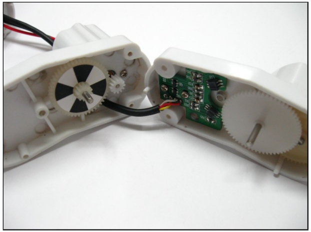


Figure: Quadrature optical rotary encoder

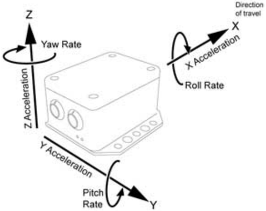


Figure: Inertial measurement unit

Hardware: How does the robot sense the world?

Additional sensor used to detect the red exit area:

- Two power sources were used to power the robot.
- DC motors are noisy and can interfere with the performance of the myRIO

Figure: 6 $\times$ 1.5V AA cells were used in series to provide 9V supply to motors

Figure: 12V 4.5Ah battery was used to supply power to myRio and Microsoft Kinect

Robot Movement: What are the choices?

Now that the robot has a physical body, can sense the world, and is powered, how should it move from one point in the world to another? There are two main choices:

Stochastic Movement

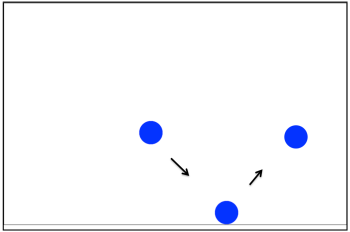


Figure: Stochastic movement sees the robot bounce around the environment in a randomised fashion.

Controlled Movement

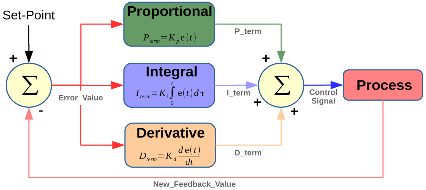
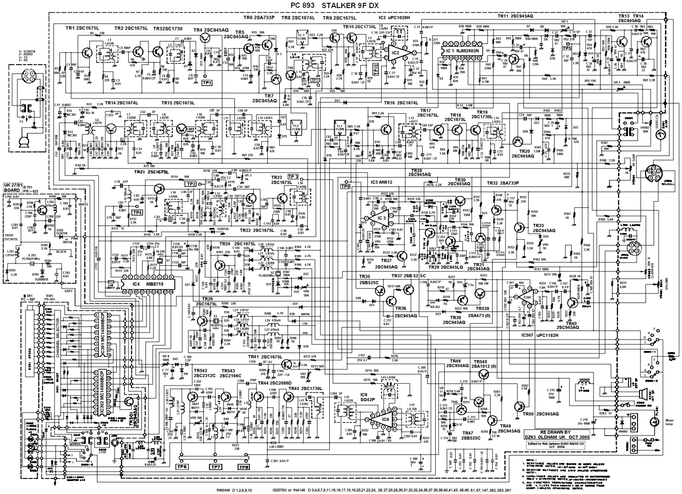


Figure: Controlled movement can move a robot to a desired location, but requires more sophisticated technology, like PID controllers.

Robot Control: Go To Goal

A picture of how the pid controller works.



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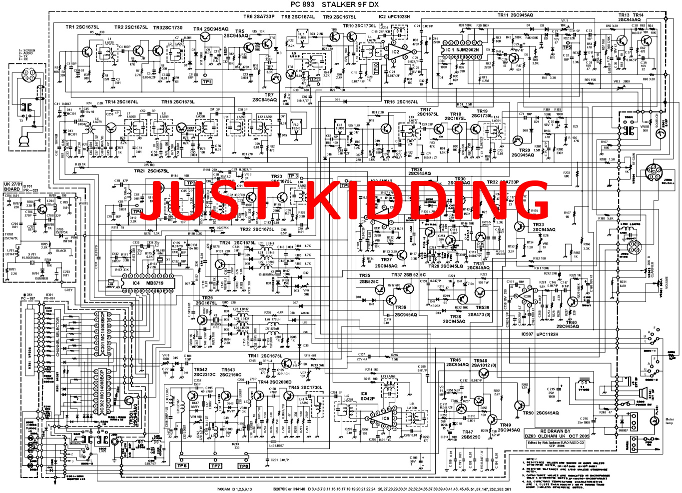

Robot Control: Go To Goal

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Robot Control: Avoiding Obstacles

- How can we create an input signal which will use the PID controller to avoid obstacles? **Vectors** ♡

- A vector from the center of the robot is made to the sensing location for each sensor.

- The sum of these vectors is used to create an input reference for the PID

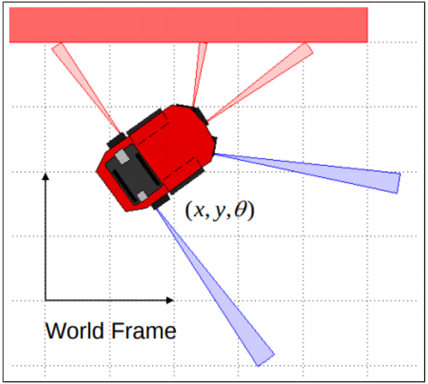


Figure: Simulated mobile robot with 5 sensors, near an obstacle

Robot Control: Avoiding Obstacles

The Story So Far...

The robot now has:

- A body, sensors, and power
- The ability to move to a desired location in the environment
- The ability to avoid obstacles

Now what?

Mapping the World: Occupancy Grids

One of the main approaches to mapping the world is to discretise the environment - this type of map is called an occupancy grid.

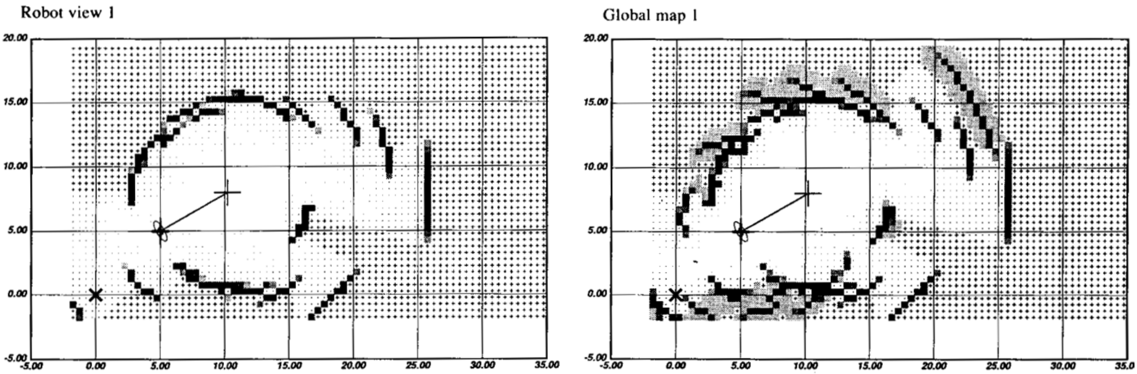


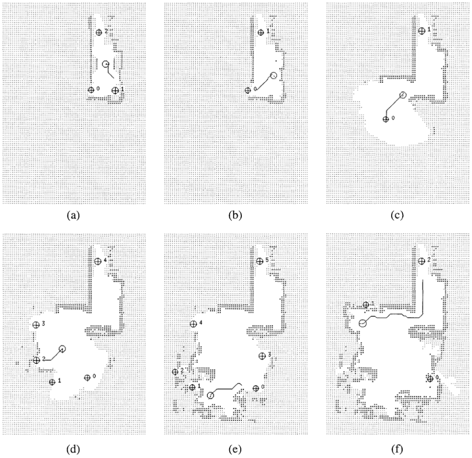
Figure: Image taken from Alberto Elfes 1989 paper *Using Occupancy Grids for Mobile Robot Perception and Navigation*

Mapping the World: Uncovering the Map

Mapping the World: Locating Objects

Strategic Navigation: Where Should We Go?

Given what you know about the world, where should you move to gain as much new information as possible?



- Frontier exploration finds the pixels which form a boundary between the explored and unexplored regions
- In our implementation, once the PID reaches its goal, it asks the strategic planner for another navigation point.
- The navigation point is the mean coordinate values of a subset of the frontier points.

Strategic Navigation: Where Should We Go?

To detect the red panel, an optical image was taken every 200 milliseconds and a colour threshold filter was used to extract a binary threshold image of red objects.

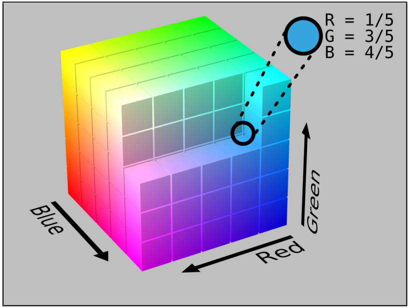


Figure: The RGB colour space is comprised of Red, Green, and Blue channels with values ranging from 0 to 255

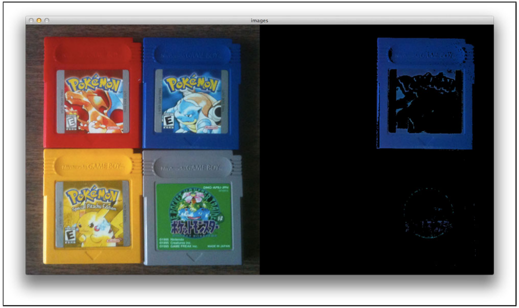


Figure: Colour detection relies on filtering out image pixels which do no fall within specified ranges for the R, G, and B channels.

Strategic Navigation: Are We There Yet?

Completed Package

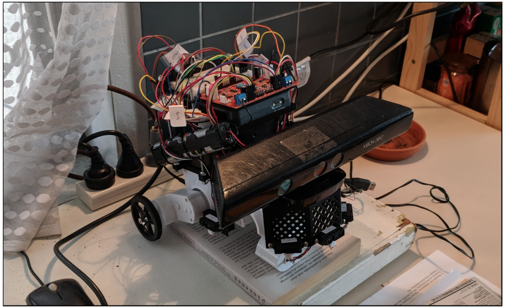


Figure: The completed robot with the Microsoft Kinect attached.

The complete package loops the following steps until the red panel is detected:

1. Look at the map and find the set of frontier pixels
2. Choose a subset of the frontier pixels randomly to determine a navigation point.
3. Pass the navigation point to the PID controller.
4. PID executes until robot is within 5cm of the desired location (or 10 seconds elapses).
5. If the robot encounters an obstacle it switches PID reference set point to avoid obstacles until the obstacle is cleared. The robot updates the map during this entire time.