INTELLIGENT GUIDE ROBOT

PROJECT PROPOSAL

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Date:

January 5, 2009

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PROJECT SUMMARY

The objective of this project is to design an autonomous mobile robot that will act as a tour guide for any visitor of the Electrical and Computer Engineering Department (ECE) at Bradley University. To meet this objective the Intelligent Guide Robot (I-GUIDE) must meet the following goals:

- Successfully navigate the ECE Department
- Behave as “human-like” as possible
- Identify key points throughout a tour
- Provide accurate information to the user
- Provide a means for user input

FUNCTIONAL DESCRIPTION

This project utilizes a Pioneer 3 Robot as the working platform for I-GUIDE. ARIA MobileSim Software and Microsoft Visual Studio software packages are used to simulate and program the Pioneer 3. The foundation and basic platform programming for the Pioneer 3 were developed in C++ during Dr. Malinowski’s Autonomous Mobile Agents [1] class (EE410). Thus, I-GUIDE is programmed in C++. Other hardware, discussed in detail later, is implemented to aid in the functionality of the robot.

The necessary goals for this tour robot are defined below. I-GUIDE must:

- Autonomously navigate the second and third floors of the ECE Department utilizing the elevator as a means of transportation between floors. Due to the complexity of the elevator problem, navigation may not be completely autonomous and some user assistance may be required.
- Perform obstacle detection and autonomously navigate around obstacles.
- Autonomously locate predefined locations throughout the ECE Department and provide audio and visual feedback while facing the user.
- Detect when the battery is low and autonomously locate the Pioneer 3 docking station.
- If time permits, further objectives include the construction of a complete system docking station, navigation of the first floor, and fully autonomous operation of the elevator.

SYSTEM BLOCK DIAGRAM

The high-level diagram shown in Figure 1 shows the overall system hardware. The laptop and the Pioneer 3 act as the main body of the robot with peripherals added to them. The Analog-to-Digital Convertor to USB (ADC-USB), barcode reader, and touchscreen transfer data to and from the laptop. All three are connected over a USB interface, while the touchscreen requires two additional inputs of a VGA port and a 3.5mm stereo jack. The speakers are indirectly connected to the laptop via the touchscreen through the 3.5mm stereo jack. The compass and the bump and sonar sensors are all connected directly to the Pioneer 3. They are powered directly from the Pioneer 3 interface ports. The laptop is connected to the Pioneer 3 using the serial port. Lastly, the laptop has an internal battery which powers itself; the touchscreen and IR sensors require external power sources, which are drawn from the Pioneer 3's battery through a DC-DC converter and a voltage regulator, respectively.

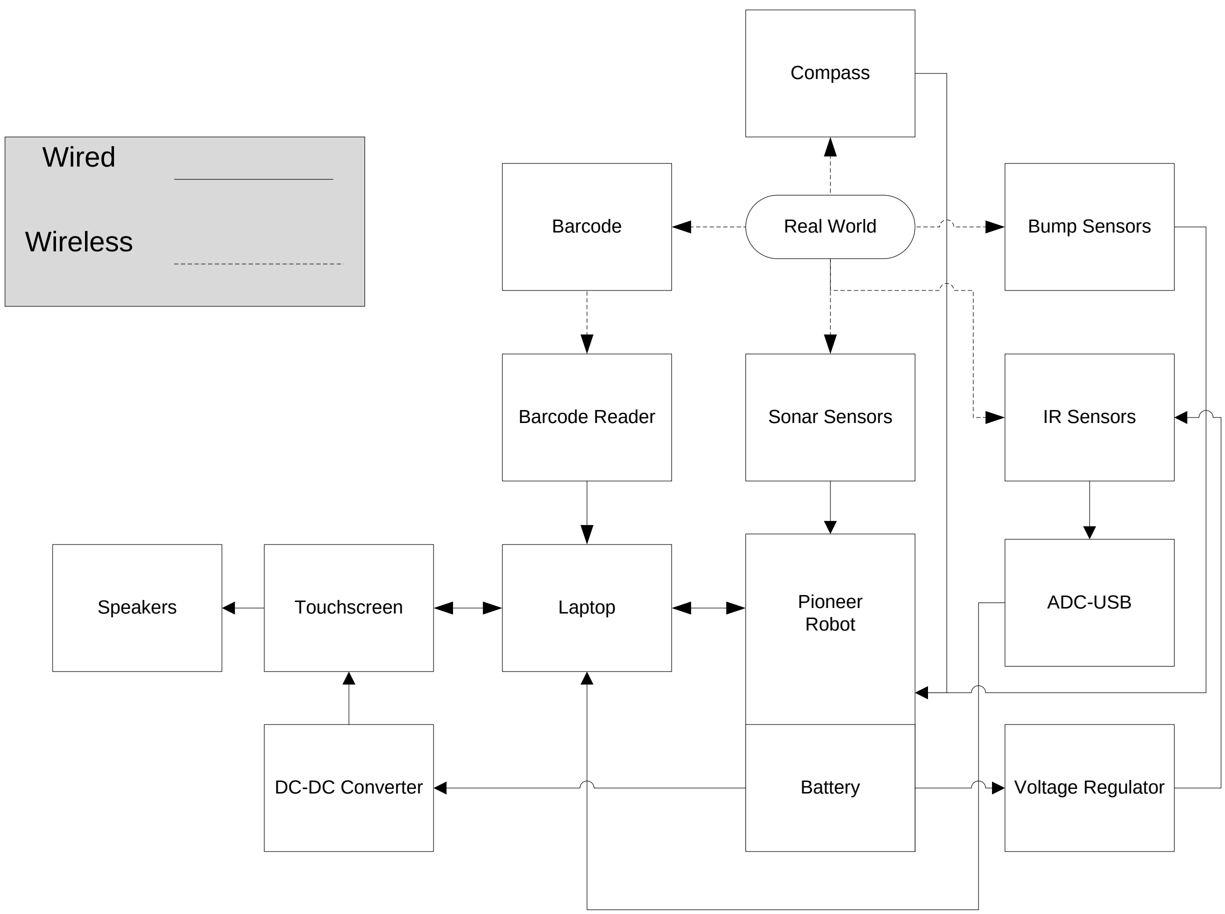

Figure 1 - High-Level Block Diagram

HUMAN INTERFACE DEVICE

Allowing the user to select a destination is a crucial part of I-GUIDE. This requires some type of human interface device (HID) that allows the user to communicate to I-GUIDE. To simplify the entire structure of the robot, a touchscreen is implemented to allow interaction to and from the user.

MONITOR / SPEAKERS

To provide the user with information in an intuitive manner, I-GUIDE requires a means of displaying pictures and video, as well as playing accompanying audio.

PIONEER 3 ROBOT

The Pioneer 3 provides a base from which to build all peripherals. The laptop, additional sensors, touchscreen, and speakers will all rest on top of the Pioneer 3. As the robot is pre-built with sonar sensors, a means of locomotion, and a battery, this project interfaces the rest of the software and hardware to the Pioneer 3.

LOCALIZATION SENSORS / MARKERS

Using solely the Pioneer 3's sonar sensors, it is possible to navigate any standard indoor environment. However, it would be difficult and time consuming to determine I-GUIDE's exact location in relation to its presumed position. The error between the presumed position and the exact location is due to various factors which include wheel slippage, non-ideal motors, non-exact tire diameters, etc. To compensate for this error, and to provide an easier and faster means of determining the robot's exact location, additional sets of sensors are implemented. Some of these sensors may require special markers placed in the operating environment.

The localization method chosen for this project is a combination of implementing a digital compass and a barcode reader. The digital compass allows the system to determine which way it is facing, thus allowing it to determine its next, and possibly shortest, route. By placing unique barcodes at pre-defined locations, I-GUIDE can read these barcodes, with the means of a barcode reader, and determine its exact position, but not bearing.

SOFTWARE BLOCK DIAGRAM

The high-level software block diagram seen in Figure 2 shows the overall setup of the software. This project is programmed in C++ because a large amount of the base programming used for the Pioneer 3 is written in C++. Also, the ARIA MobileSim software simulation package is utilized for simulation of various algorithms for the Pioneer 3.

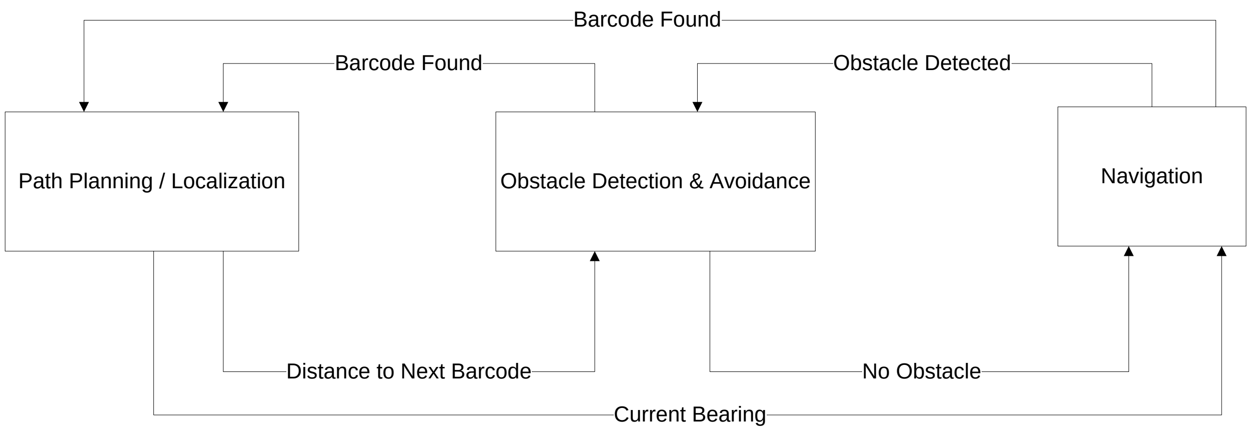

Figure 2 - High-Level Software Block Diagram

NAVIGATION

The navigation logic block controls the robot's most basic function, namely, driving down the middle of a hallway. This is also the main software loop for I-GUIDE. The logic of this block is driven by inputs from the sonar and IR sensors along with the digital compass. Control of the robot is only relinquished when either an obstacle is detected or a barcode is found.

OBSTACLE DETECTION & AVOIDANCE

The obstacle detection and avoidance logic block controls the robot's main survival function, namely, not to collide with any obstacles or people. This logic block utilizes the sonar, IR, and bump sensors to detect and navigate around any obstacles. In this logic block, control is only released if either a barcode is read or the obstacle is no longer present.

PATH PLANNING / LOCALIZATION

The path planning / localization logic block controls I-GUIDE's highest function, which is navigation to a desired location. This logic block determines the correct course to take based on its internal topological decomposition map, current position, and the required heading to reach its next destination. The proper heading is determined by the digital compass. This logic block also provides the audio and visual feedback to the user when the final goal, selected by the user via the touchscreen, is reached. Upon completion of the path planning, which includes providing feedback to the user, control of the robot is relinquished to the navigation logic and the distance to the next barcode is passed to the obstacle detection and avoidance logic.

FUNCTIONAL REQUIREMENTS & PERFORMANCE SPECIFICATIONS

The success of this project depends on the accuracy of the position and response speed of the robot. Since I-GUIDE is designed to interact with humans, normal human interactions with the environment shall serve as a baseline for the robot. Furthermore, humans function well in real-time navigation and decision making, so human reaction time shall serve as a baseline for the robot.

The robot must locate its desired position within a 4' radius. This is half the width of the hall and close enough that humans will understand which landmark the robot is discussing while giving the tour. I-GUIDE must also be able to navigate through its environment while avoiding any obstacles and maintaining a speed no greater than the average human walking speed, which is 31.5in/sec [6]. The obstacles encountered by I-GUIDE may be both stationary and moving. This requires a specified range sensor accuracy as well as magnetic bearing accuracy. The sensors must have a range of 6" to 10' to detect both sides of a hallway, detect obstacles early enough to correct I-GUIDE's trajectory, and ensure that the robot bypasses the object safely. The sensors must also have measurement accuracy of at least ±5" to allow a minimum distance from an object of 1". The magnetic bearing accuracy must be within 10° to provide accurate localization. This is the maximum bearing error that allows I-GUIDE to drive straight down its longest path while staying greater than 1" away from the wall. Operating in a real-time environment and interacting with humans demands that the robot reacts faster than a human being. Human reaction time is 180ms [6]. I-GUIDE must also allow the user to select any of 28 destinations within the ECE department, including classrooms, faculty offices, and laboratories. Lastly, the robot should detect when the battery is at 10% of max charge and plan accordingly to preserve the system.

PERFORMANCE SPECIFICATIONS SUMMARY

I-GUIDE shall be capable of:

- Reaching intended goals within a 4' radius
- Avoiding all obstacles, moving or stationary
- Detecting when battery is at 10% of max charge
- Responding to all stimuli in less than 180 ms (maximum runtime for software loop)

- Maintaining an average speed of 31.5 in/sec during transit
- Allowing users to select one of 28 locations or one of 3 complete floor tours

Additional sensor specifications include:

- Distance/Proximity sensors with a minimum range from 6" to 10'
- Distance/Proximity sensors with a minimum accuracy of ±5"
- Compass sensor accurate to within ±10°

SCHEDULE

WORKFLOW

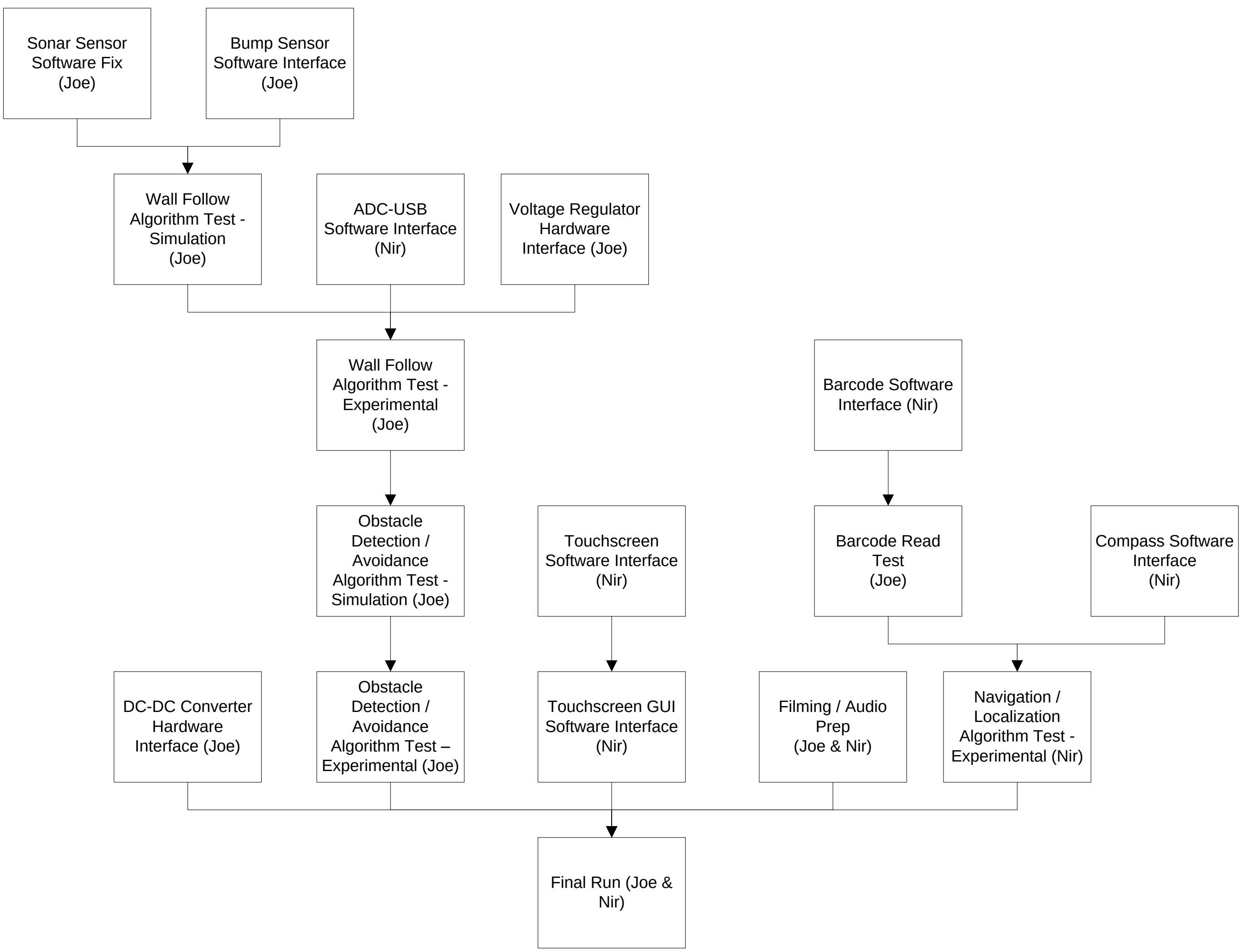

Figure 3 - General Workflow

In Figure 3, the general workflow, dependencies, and division of labor are shown. This model drove the Gantt and PERT charts, which follow in Figure 4 and Figure 5. The Gantt chart visually represents the tasks that need to be completed each week in sequential order, while the PERT chart is a detailed map of times, dates, and dependencies of the project.

GANTT CHART

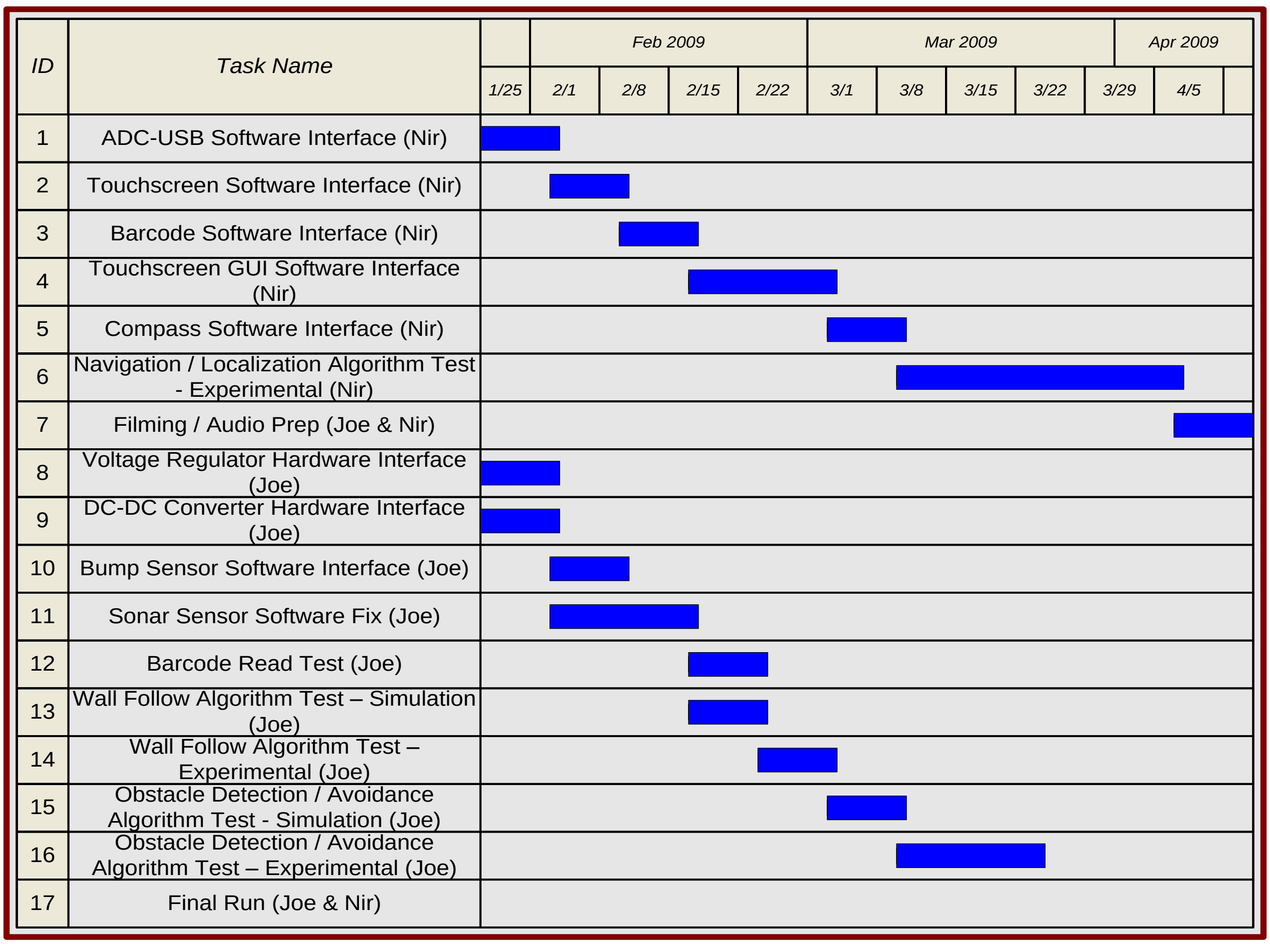

Figure 4 - Gantt Chart

PERT CHART

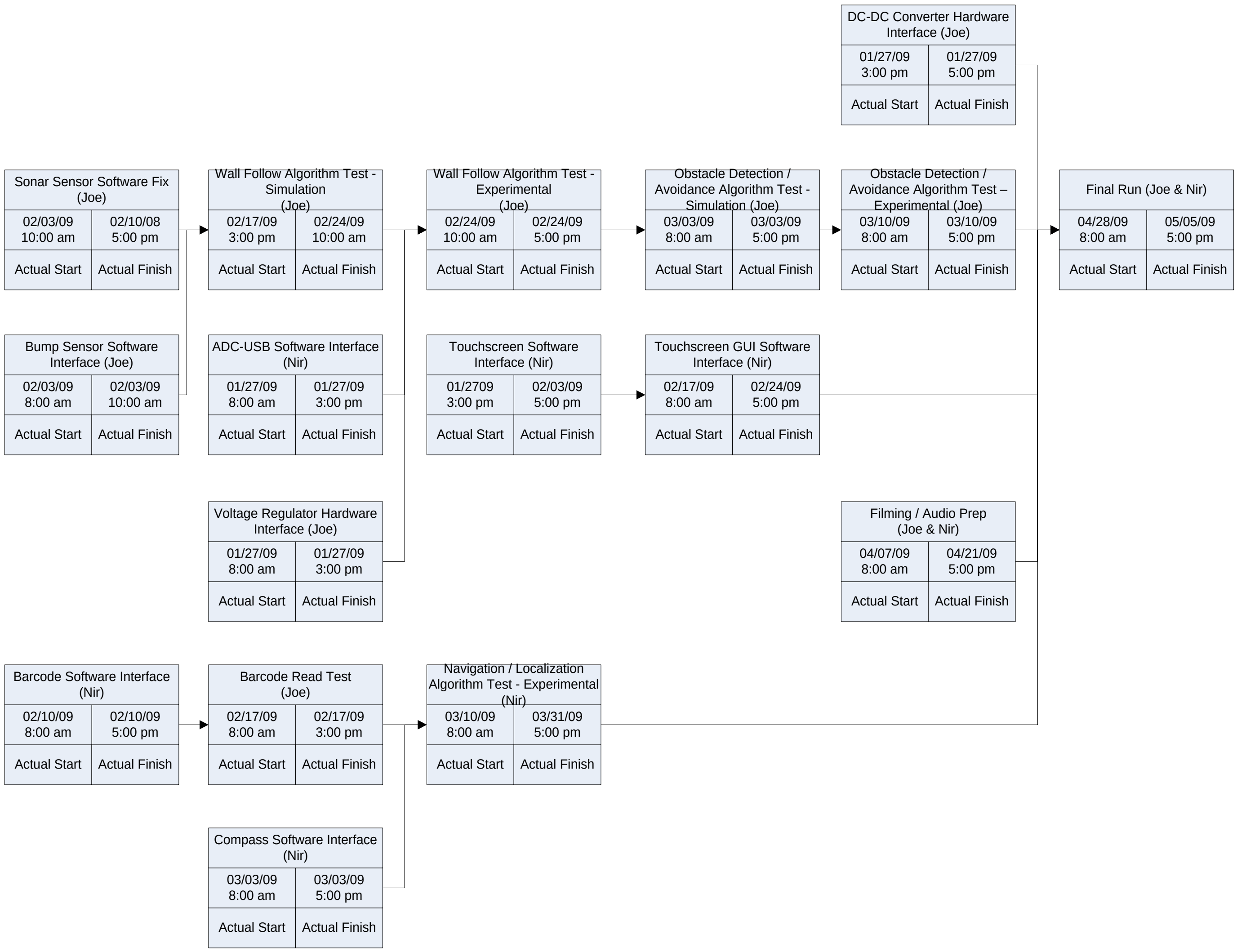

Figure 5 - PERT Chart

EQUIPMENT AND PARTS LIST

Component	Vendor	Part Number	Crucial Spec.	Unit Cost	#	Department Obtained Verified	Ordering Cost
Touchscreen	3M	11-81375-225		$ 100.00	1	X	
Speakers	Cyber Acoustics	CA-2908	Portable	$ 40.00	1		$ 40.00
IR Sensors	Sharp	GP2Y0A 700K	Max Range >= 9'	$ 12.50	8		$ 100.00
Barcode Reader	Wasp	WLS8400 ER	USB, Max Range >= 9'	$ 600.00	1		$ 600.00
Rear Sonar Sensors	ActivMedia	ACAX032		$ 470.00	1		$ 470.00
Compass	ActivMedia	ACT012		$1,395.00	1		$ 1,395.00
DC-DC Converter	Recom	RP30-1212SF	30W, 12V Input, 12V Output	$ 110.00	1		$ 110.00
Bumper	ActivMedia	ACAX013		$ 945.00	1		$ 945.00
ADC to USB with Terminal Board	Pico Technology	PP241	8 Channel, 8bit	$189.00	1		$ 189.00
Voltage Regulator	National Semiconductor	LM317T	5V, 30mA	$ 1.86	1		$ 1.86
Pioneer 3	ActivMedia	P3X0001		$3,695.00	1	X	
Grand Total							$ 3,850.86

Figure 6 - Parts List

The table in Figure 6 contains all of the foreseeable parts and equipment necessary to order. This list does not contain wiring costs or smaller, available components such as standard resistors and capacitors. Lastly, this table does not reflect the cost and need of a physical platform that needs to be built on top of the existing Pioneer 3 to support all of the peripherals and bring the touchscreen to a more accessible height to users.

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