

Nautical Autonomous System with Task Integration

Project Proposal

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Project Summary:

The student members of Team NASTI propose the Nautical Autonomous System with Task Integration (NASTI), an autonomous system based around a hovercraft platform, as the basis for a senior project. The platform will be designed in such a way that it can autonomously navigate a channel of water buoys. Ultimately, the robotic platform is intended to compete in the AUVSI (Association for Unmanned Vehicle Systems International) and ONR's (Office of Naval Research) 5th International RoboBoat Competition. This competition is based around the main goal of navigating an unknown path of water buoys and running through a speed test straightaway. If a vehicle can complete this, then there are sub tasks that can be completed for extra points. The scope of the senior project contains the image processing and control system for navigating the channel, and the rest of the competition will be taken as secondary goals for the team. The goals, both the navigational and the competition goals can be seen in Figure 1-1.

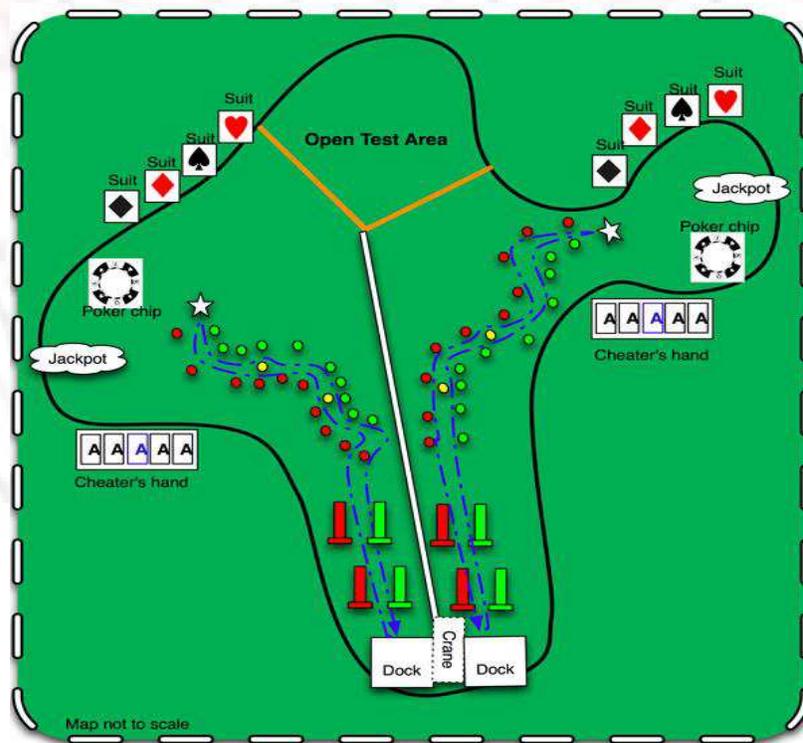


Figure 1-1 Competition layout

Detailed Description:

The following is a detailed description of the project. It includes the goals of the team for the senior project and the competition, a detailed description of the overall system and the sub systems, a detailed parts list, and the design specifications.

Goals:

As stated above, the ultimate goal of this project is to create a hovercraft system that can autonomously navigate a course laid out by water buoys. The intermediate goals are as follows:

- Develop a functional image processing system for buoy detection
- Develop a data acquisition system to collect velocity and acceleration data
- Create an autonomous navigational system for a hovercraft based on image processing, velocity and acceleration
- Integrate image processing into an embedded CPU/DSP/GPU

Overall System Description:

The main system is comprised of many subsystems that shall be melded into one fully functional nautical autonomous system. The main components of the system will include a BeagleBoard, a data acquisition uController, a thrust uController, power electronics, and an imaging device. The i/o characteristics are outlined in Table 2-1 on the following page and the system can be seen in Figure 3-1.

Table 2-1 Input/Output Signals to/from Control Units

	Inputs	Outputs
BeagleBoard	Camera Images	Thrust Control Signal
	Inertial data	
	Wireless Communication	Wireless Communication
Data Acquisition uController	Accelerometers(2+)	Inertial Data
	Gyroscope	
	GPS	
	E-stop switch	
Thrust uController	Thrust Control Signal	Thrust
		Starboard-Stern Control Fan
		Starboard-Bow Control Fan
		Port-Stern Control Fan
		Port-Bow Control Fan
		Bow/Braking Control Fan

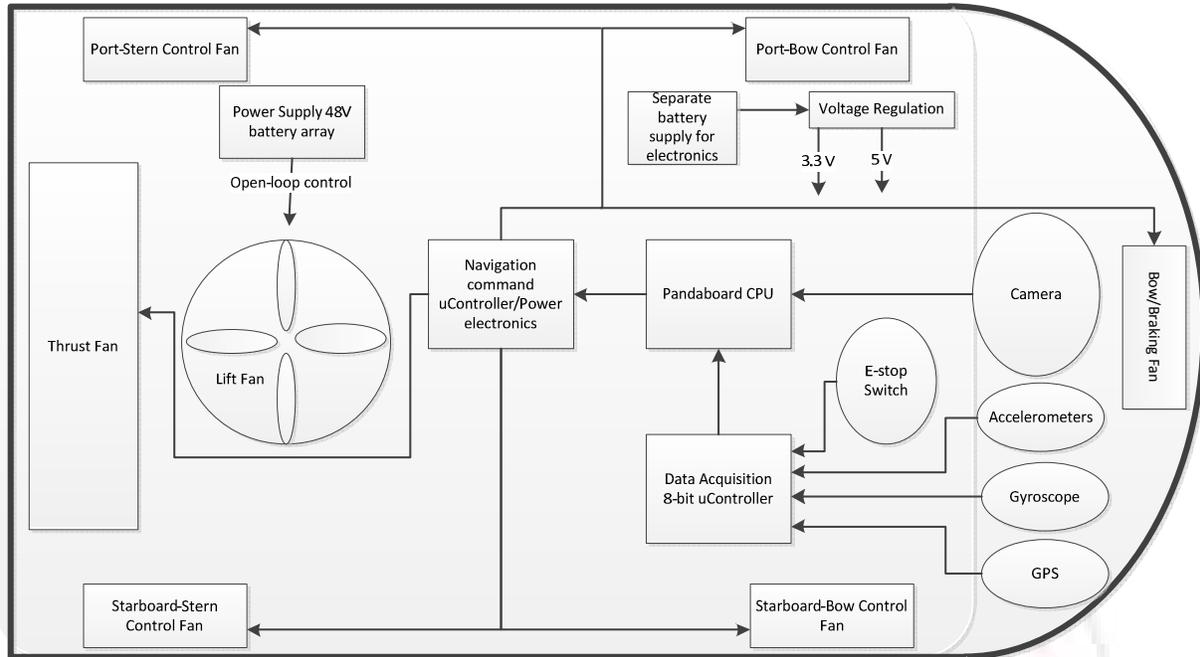


Figure 3-1 – Functional System Diagram for the NASTI

Sub-Systems:

The following is a complete description of all of the subsystems that will be present on the hovercraft.

Central Control Unit:

The Central Control Unit (CCU) will be based on a BeagleBoard (Figure 3-2) CPU/DSP/GPU development environment.



Figure 3-2 BeagleBoard Platform

The BeagleBoard will be running a Linux based operating system and will be performing most of the heavy computations for the project including computing the overall control signal, image processing, wireless communication, data interpretation, and overall mission state control. If time allows most of the image processing code will be ported to the DSP to reduce computation time. The state control can be seen in Figure 4-1.

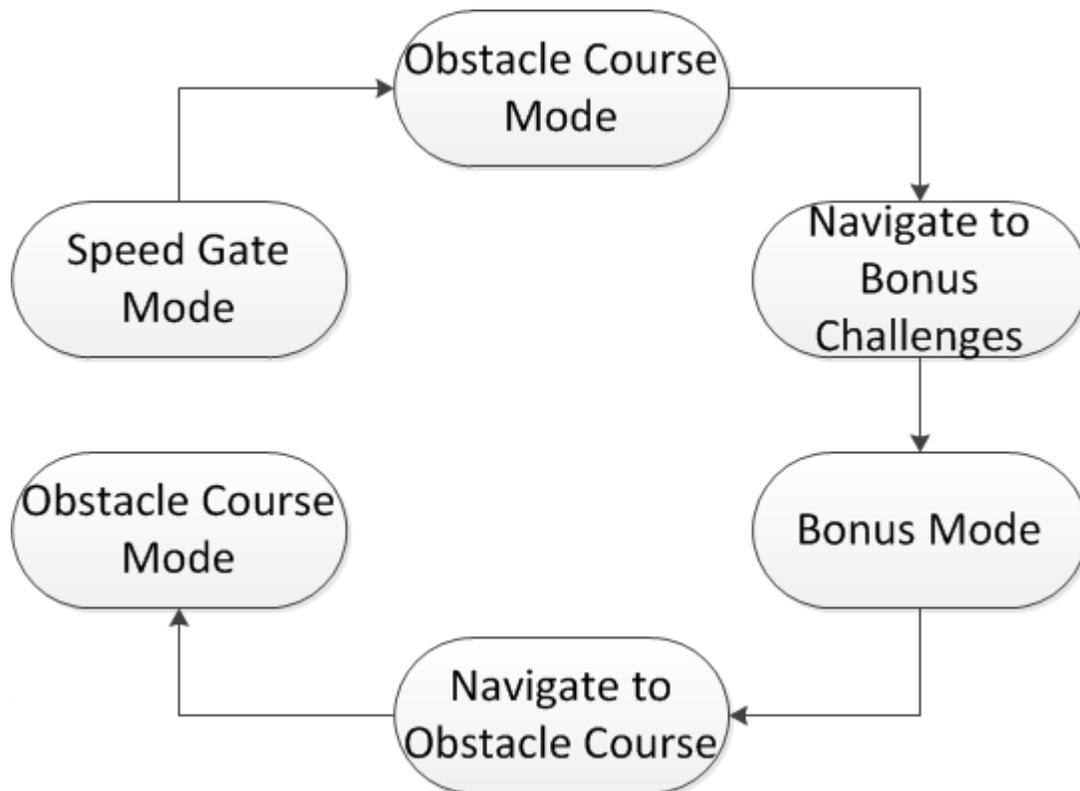


Figure 4-1 State flow diagram

The BeagleBoard will also be determining the main control signal that the craft is to follow through the obstacle course. This signal will be computed based on the data that is acquired through the processing any analysis of the incoming image signal from the camera. The horizon of the water (where the water meets the shore) will first be determined to potentially reduce the computation area for the rest of the image, as outlined in Figure 4-2.

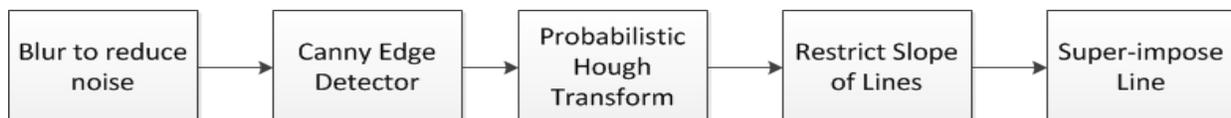


Figure 4-2 Block Diagram for Horizon Detection

The sub image will then be processed as in Figure 5-1 to determine the buoy location in the image and the characteristics of the buoys.

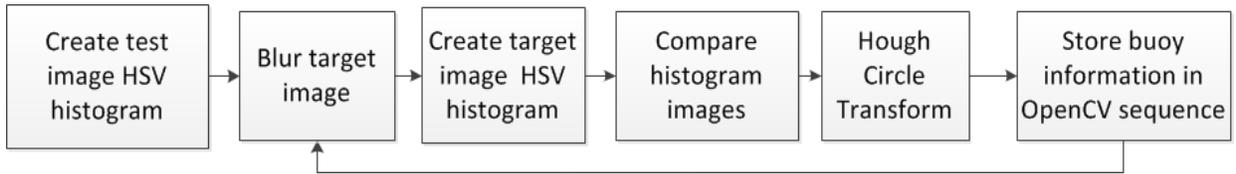


Figure 5-1 Block Diagram for Buoy Detection

Once the buoys have been discovered, they can be paired up, sorted closest to farthest pairs, and boundary lines can be extrapolated as in Figure 5-2.

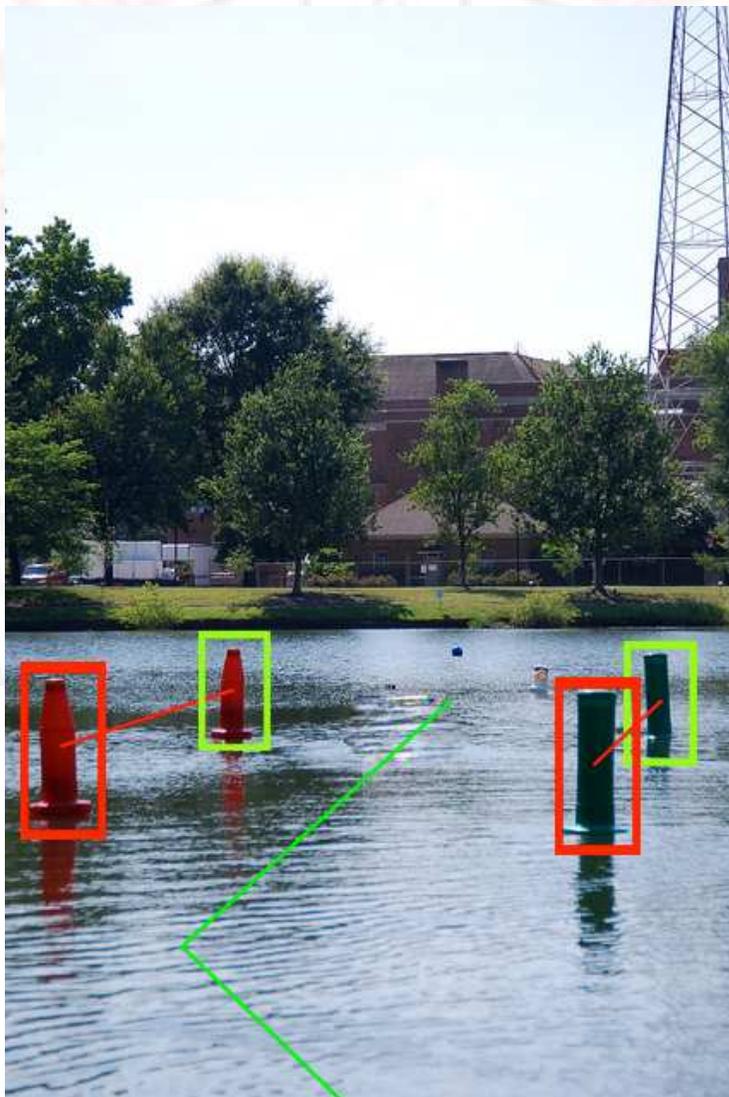


Figure 5-2 Navigational Signal

This navigational signal can be seen in Figure 5-2 as the green line passing between the middle of the 'boundary lines' that are extrapolated between the first and second set of red/green buoys.

Data Acquisition:

The data acquisition system will be performed by a uController and an overall position/velocity/acceleration signal will be sent to the BeagleBoard for further analysis. This system is described in Figure 6-1.

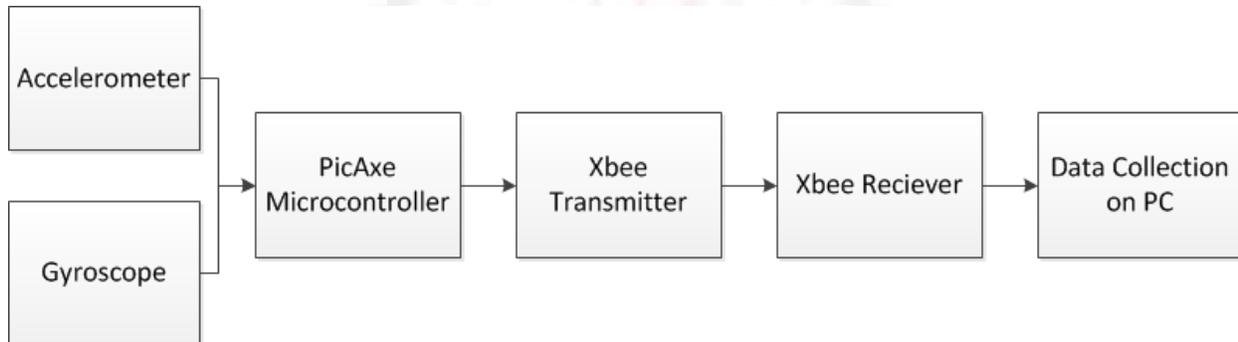


Figure 6-1 Data Acquisition Block Diagram

As can be seen in Figure 6-2, the inertial data will be collected from a series of accelerometers and gyroscopes. This data will then be processed on the uController to determine the basic positioning information and transmitted to the BeagleBoard. Currently the diagram shows a wireless communication, this is the current set up to test the wireless communication channels and testing purposes, but the signal will eventually be switched to a wired connection.

Stability:

Stability will be handled by the thrust uController. This structure has been decided to reduce the reliance on the BeagleBoard to maintain stability of the craft. The BeagleBoard has an excruciatingly long start up time if the board was to malfunction and restart or the operating system on the board could crash or lockup. If this was to happen and the craft was under complete control by the BeagleBoard then it could become unstable and drive uncommanded. Thus, using the navigational command signal determined in Figure 5-2, will be considered as the crafts central 0 heading as in Figure 7-1 on the following page. The error signal will result in control of the port & starboard thrusters being commanded to maintain a 0 heading.

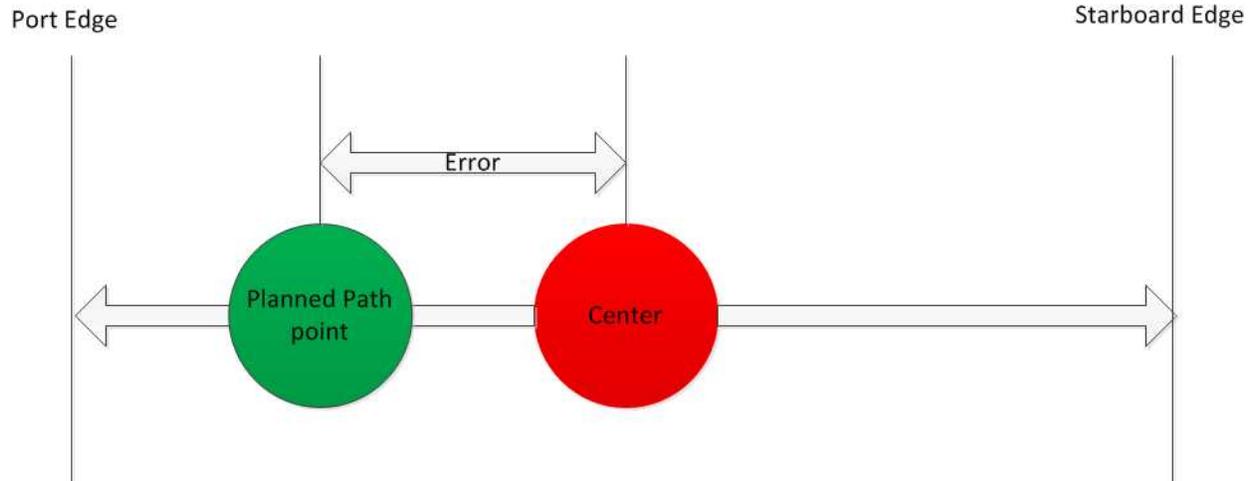


Figure 7-1 Stability Control Signal

Navigation:

Navigation will rely on the complete integration of all of the systems, as is shown in Figure 7-2.

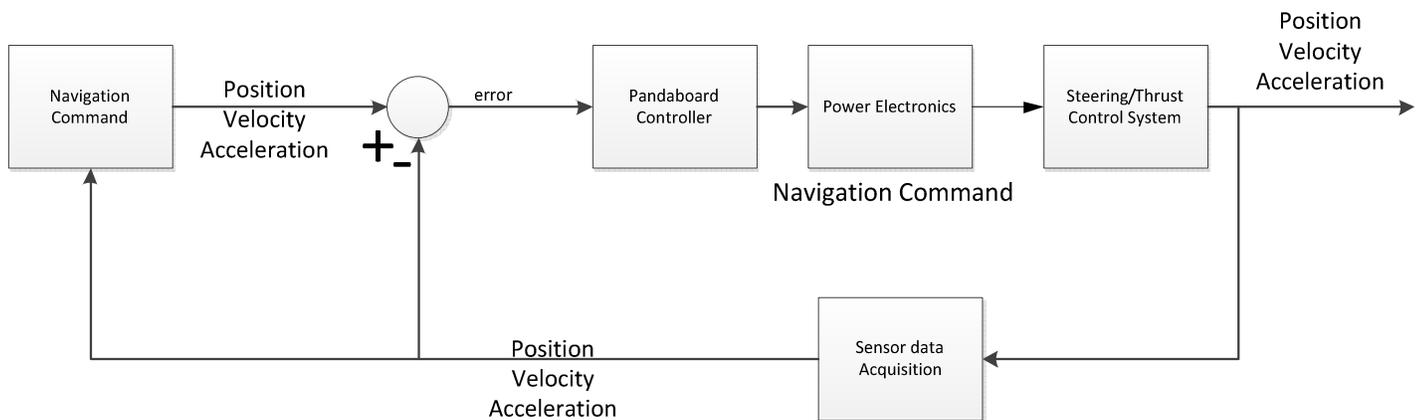


Figure 7-2 Navigational Control Block Diagram

The image processing must correctly determine the buoy location, then the BeagleBoard will determine a navigational bath, the thrust controller must maintain correct heading, and the power electronics must function accordingly to allow navigation. The overall navigational signal will be a vector indicating a heading and velocity as in Figure 8-1 on the following page.

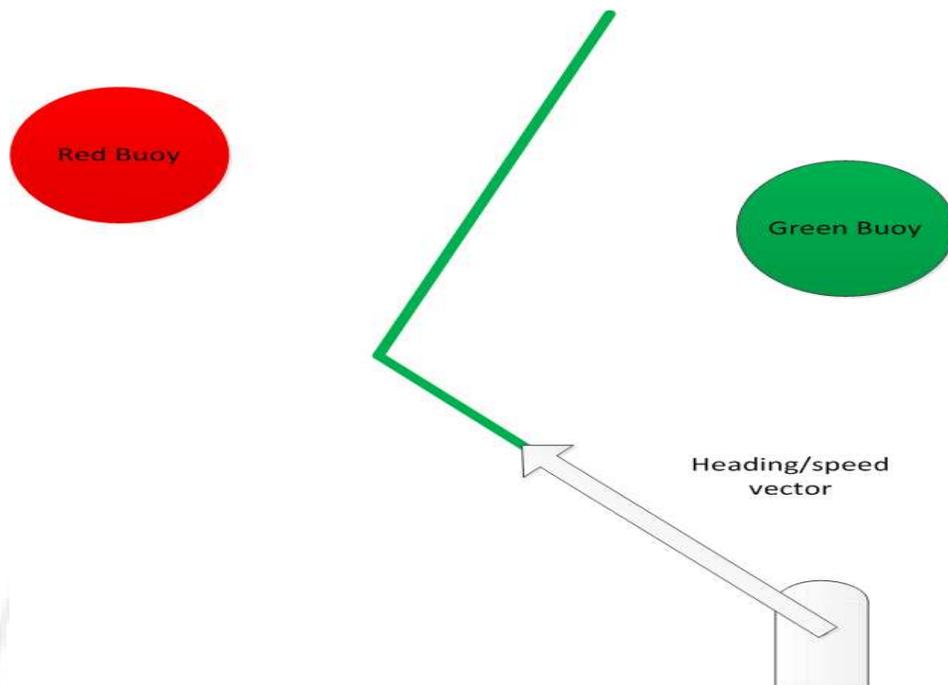


Figure 8-1 Navigational Signal from a Top View

Parts List:

The following list contains a preliminary listing of the parts that shall be included in the final design of the autonomous system.

- Lift Fan
- Main propeller for thrust
- 4x small thrust fans
- BeagleBoard
- 2x 8-bit microcontrollers
- X-Bee wireless adapters
- Camera
- Gyroscope
- Accelerometers
- Materials for final body of hovercraft

Design Specification:

This section will list all of the technical requirements and performance specifications

Data Acquisition:

- A camera parallel to the surface of the water shall be the main method of collecting data
- An additional camera shall be mounted higher and aimed downward for a bird's eye view
- Gyroscopes and accelerometers shall be used for stability control
- The gyroscope and accelerometer data shall be fed into 8-bit microcontrollers
- The 8-bit microcontrollers and cameras shall be fed into a PandaBoard for further processing
- The BeagleBoard shall have an embedded Linux installation with OpenCv installed for image processing

Stability:

- The inertial data shall be used as the input to a stability control system
- The control system shall utilize a propeller at the rear of the vehicle for thrust and 4 smaller fans (2 on each side) for precision steering

Navigation:

- The system shall first locate the horizon of the image
- The system shall then locate the buoys below the horizon of the image
- The system shall then classify the colors of the buoys, and assign distances based on geometry
- The final path shall be planned based on these distances
- The system shall keep the red buoy on the right [1]

Mechanical Characteristics

- The weight shall not exceed 35 lbs
- The maximum speed shall be 10mph
- It shall take a maximum of 10 seconds to accelerate to the final velocity
- There shall be 5 lbs of thrust from the rear propeller

Schedule of Work:

Appendix A depicts the proposed preliminary schedule for the remaining tasks this semester, as well as the tasks that need to be completed for next semester.

Conclusion:

To sum this project up, it is a highly software intensive system that requires a synergistic environment between numerous sub-systems. The main buoy navigation and obstacle avoidance is a handful, as each subsystem can be considered a project in-and-of itself. The integration could also be a separate project. However, the team has clearly outlined the goals, determined the system and sub-systems, developed control algorithms, defined the necessary components, and provided an outline for the remaining work. Team NASTI is up to the task, and the team feels this is a feasible senior project. For this reason, and the information provided in this report, we propose to move forward with the development of the Nautical Autonomous System with Task Integration.

The hovercraft design is our primary focus at this time. The ultimate goal of this project is to achieve the performance tasks set forth in the AUVERSI RoboBoat competition rules. If performance and control issues force us to consider a more traditional boat platform, the hovercraft idea will be tabled in favor of a design to meet these needs. It should be noted that the same basic control issues that we outlined for the hovercraft will also exist in a traditional boat platform as well. The mode of transportation, be it a conventional boat or hovercraft, will not have any affect on the image processing aspect of the project.

Sources

[1] “*The Four Elements*” 4th International RoboBoat Competition Final Rules. Arlington, VA: AUVSIfoundation. PDF.

[2] Bradski, Gary Rost., and Adrian Kaehler. *Learning OpenCV*. Beijing: O’Reilly, 2008. Print.



Appendix A Proposed Schedule of Remaining Work

Weeks	Major Deliverable
13-Nov	
	Finalize BeagleBoard environment
	Have a prototype buoy detection program
	Begin design of communication channel between uC and BeagleBoard
	Perform mechanical testing on Mark 1 prototype (drag, acceleration, weight restrictions)
20-Nov	
	Gyroscopes and accelerometer communication channel development
	Begin construction of communication channel between uC and BeagleBoard
	Continue to evaluate Mark 1 prototype
Weeks	Major Deliverable
27-Nov	
	Decide whether to improve hovercraft platform or switch to a catamaran platform
	Begin developing PID stabilization for craft
	Begin developing path planning algorithm using buoy/horizon detection
Dec-Jan	
	Continually tune and develop path planning/stabilization controls. Finish high level command system.
Weeks	Major Deliverable
Feb	
	Begin actual testing of fully integrated platform.
March	
	All high level designs will be done at this point. The controls and vision algorithms will be continually improved. Begin developing designs for bonus tasks.
April	
	Complete the design for any bonus tasks and begin the testing of these systems
May	
	Be able to demonstrate path planning and stable navigation for final presentation