

Design Report

# SQUINTY



by

IniTech  
for



**14<sup>th</sup> Annual Intelligent Ground Vehicle Competition**

**UMBC**  
AN HONORS UNIVERSITY IN MARYLAND

University of Maryland: Baltimore County:

Erik Broman (Team Lead and Requirement Lead)

Albert Hsu (Design Lead)

Sean Wilson (Coding Lead)

Hussenia Ozigi Otaru (Testing Lead)

UMBC IEEE members

May 25, 2006

**SQUINTY  
DESIGN REPORT**

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## 1. Introduction

### 1.1 Purpose of This Report

This report serves the purpose of providing the user or client with the System Design development and an explanation of its components, highlighting unique innovative aspects of the design, as well as intelligence aspects of the Squinty system for autonomous challenge. Since the navigation challenge is planned to be completed, the system used for navigation event will also be detailed.

### 1.2 Team Organization

The Initech team is comprised of undergraduate students from multiple disciplines, such as Computer Engineering, Computer Science, and Mechanical Engineering, who are all enrolled at the University of Maryland: Baltimore County (UMBC) and who are also part of the UMBC IEEE student branch. Two members are returning who entered in the previous intelligent ground vehicle competition, Albert Hsu and Erik Broman. Development phase leaders were elected to make the project process run smoothly by having a team lead, requirement lead, design lead, coding lead, and testing lead.

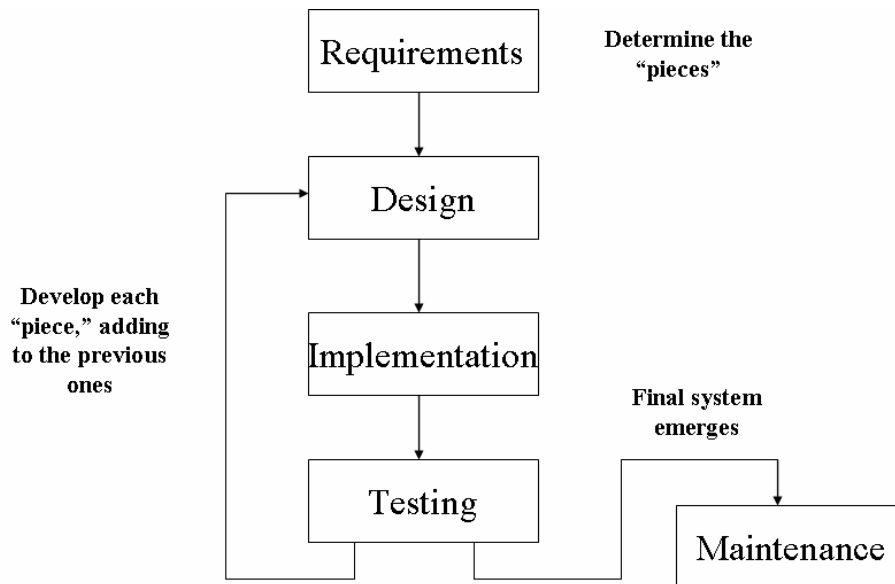
Name	Class and Department	Phase Leaders	Hours
Erik Broman	Undergraduate, Computer Engineering	Team Lead and Requirement Lead	120
Sean Wilson	Undergraduate, Computer Engineering	Coding Lead	120
Albert Hsu	Undergraduate, Computer Engineering	Design Lead	94
Hussenia Ozigi Otaru	Undergraduate, Computer Engineering	Testing Lead	81
Steve Sapp	Undergraduate, Computer Engineering		20
Andrew Wilson	Graduated, Computer Engineering		30
Emmanuel Oduroja	Undergraduate, Computer Science		30
Andrew Stowell	Undergraduate, Mechanical Engineering		70
		Total Hours	565

## 2. Design Development

The design development of Squinty took the approach of refitting and adding additional features to the previous design of the “Should be Trivial” robot, which was entered into the 13<sup>th</sup> intelligent ground vehicle competition (IGVC). Throughout September 2005 to December 2005, the Initech team discussed many improvements and additional requirements to add to the 14<sup>th</sup> IGVC vehicle, so that next year from January to the day of the competition, the implementation and testing processes could be performed on the Squinty system.

### 2.1 Incremental Development

The development of the previous entry, “Should Be Trivial”, was performed for the 13<sup>th</sup> IGVC with navigation in mind but not implemented. After the competition, the autonomous challenge code was improved, and currently the team is working on the navigation challenge. Therefore, the development of the project was closely related to the incremental development approach shown in Figure 1.



**Figure 1: Incremental development**

An iterative process was used between the design and implementation phases, because of the configuration needed to integrate new components.

### 3. Design Processes

The Squinty vehicle will be entered into the autonomous and navigation challenge for IGVC. There were significant improvements in the performance of the current implementation of the vision detection algorithm. The highlight of the autonomous challenge is the image processing path and detection algorithm, and the highlight of the navigation challenge is the GPS navigation algorithm.

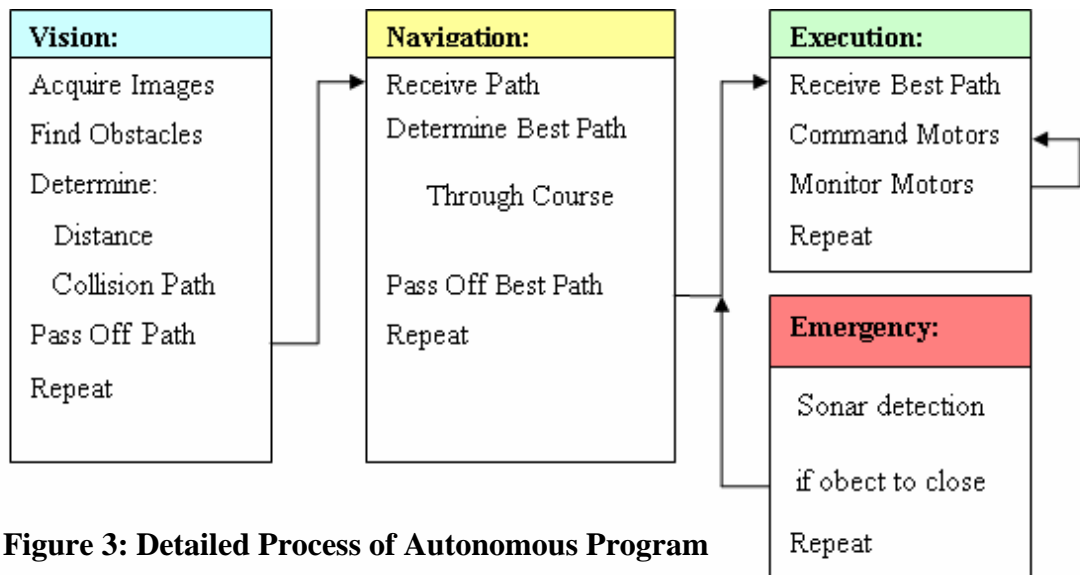
#### 3.1 Vehicle Mechanical Specification and Design

Squinty is a vehicle with two front wheel drive motors using differential steering. The vehicle's movement is driven by an assortment of inputs: camera images, sensors, motors, and safety components designed for the autonomous and navigation challenge for the IGVC.

##### 3.1.1 Software Program Design

All control of the vehicle is performed by a Dell Inspiron 1150 Laptop running Ubuntu Linux version 6.06 beta 2 Operating System, a change from the use of Fedora Core 2 Operating System last year. Ubuntu is a free, stable, and well designed operating system that is not too resource intensive.

The program to run Squinty was developed in C/C++ and was split into four essential processes which are run in parallel: vision & sonar, navigation, execution and emergency conditions. A detailed process is shown in Figure3.



**Figure 3: Detailed Process of Autonomous Program**

The Navigation process will differ between the autonomous and navigation challenges, since the inputs that will determine the path decisions made will change between the cameras and the GPS device. Further details will be explained later in this report.

In execution, the command to drive the motors is written to shared memory, where the navigation code reads it and sends a pulse width modulation (PWM) signal to the motors through the Brainstem micro controller to a RoboteQ motor controller, which powers the two motors. The PWM signal commands the motors to perform basic driving instructions: Turn left, turn right and drive forward.

### 3.1.2 Primary Vision Sensory Component

Vision to the vehicle is the most important part of detecting obstacles on the road, looking for distances to objects, their colors, and shape. How do we perform those actions? One technique is to use a camera to take an image and process them to the specifications of the challenge.



The Unibrain Fire-I Board Firewire camera was used for the vision portion of the system. We are using only one camera; hence the name ‘Squinty’. First, the camera is adjusted to the light at the beginning of the program, looking for obstacle colors orange, yellow and white and specifying the range of them in terms of red, green and blue values. The code utilizes the OpenCV open source image library in the program for vision functions.

The image takes a low resolution image (300x225 pixels) to decrease the number of pixels to process, and filters out non obstacle colors for detection. When the colors were found, the vision program groups those colors to find the boundaries of an object and passes these boundaries to the navigation process. This cycle is repeated an average of 10 frames per second, an improvement of 1 frame per second from last years design.

### 3.2.2 Secondary Hardware Components

#### 3.2.2a Sonar Sensor Hardware

Squinty's camera can only see what is directly in front of the robot. As such, if the robot needs to make a turn but there is an obstacle to the side of the robot, then the robot will not be able to know whether it can make the turn correctly. Therefore, the sonar sensors will be placed on the left and right sides of the robot to ensure that it will not be impeded by obstacles while making a turn.

#### 3.2.2b Navigation Hardware

Squinty will read GPS inputs from the Laipac TF30 global positioning system (GPS) module. The component provides the necessary latitude and longitude so Squinty can plan a path to reach a waypoint.



Another component to the navigation is the compass, a Devantech CMPS03 IIC Digital Compass. The compass was used with the GPS to provide the current heading of Squinty, which provides data to create correct paths to waypoints.

#### 3.2.2c Motors & Control Hardware

The two NPC-02446 motors were used, replacing the powerful E-tek motors from last years competition. The new light weight motors have better mobility, and are cost efficient. In addition, the motors connect to the RoboteQ motor controller that receives commands from remote controls and microcomputers to drive the two motors.

### 3.2.2d Micro-controllers

All the processes of secondary devices go through the Arconame Brainstem micro-controller. It provides a variety of I/O functions for Squinty systems.

Combining programmability and a built-in command set, this module is both a stand-alone controller and real-world interfacing tool. A Brainstem program is written in The Embedded Application (TEA) language for the brainstem. TEA is a subset of C language, and controls the Compass and the Motor Controller.



### 3.1.3 Vehicle Safety Component

The emergency stop (E-stop) function is a required feature for an IGVC robot. Our E-Stop system consists of a remote control keyfob system and a large button on the back of the Squinty robot. Either method will shut off the robots motors.

## 3.2 Autonomous Challenge Navigation: Path Planning

The obstacle path was passed from the vision help the navigation to determine the collision path, were not to go. This was done by using five 'feeler' coordinates. If there is obstacle color that shares the same x coordinate as one of these five 'feeler' coordinates, collision is registered. When collision path to the left half of the image occurred, it will command Squinty to go right and vise versa. Squinty will proceed straight if there is no obstacle expecting that an obstacle will appeared either on the left or the right. The process is repeated every time the image is filtered.

## 3.3 Navigation Challenge Navigation: GPS Algorithm

At the start of the program of Navigation Challenge, the GPS (The Laipac TF30) will read in the waypoints from a file, get the current heading,



bearing, and coordinates of itself and place the waypoints on a virtual x y coordinate map.

This map was split into four even grids. The robot tries to find the most 'clustered' waypoints on the map. A list then is generated of the priority of each grid, based on the most clustered sectors of the map. This accomplishes the goal of getting to the most waypoints in the shortest amount of time. Squinty will head to the first waypoint on the list using the current bearing and location with the help of the vision portion to detect obstacles. The compass and GPS constantly re-map the robot's position on the map, updating the robots location.

#### **4. Efficiencies of Resources**

Resources in the real world are limited and engineers are required to be efficient in using them. Furthermore the resources are limited by the budget of how much each material costs and the amount of space it takes up on the vehicle.

##### **4.1 Battery Power**

Squinty has multiple power sources: one for the motors, one for aux components and one for the laptop. In order to keep vehicle sensors' electronics isolated from voltage transients generated by the motors, a separate battery was selected for the drive system. In an effort to save space, only one battery was used (12V 33Ah deep cycle Sealed Lead Acid). The laptop draws its power of its battery that last 2 and half hours. Lastly, the aux components draw power from set of two 12 V battery packs mounted in the vehicle.

##### **4.2 Materials Data**

The entire Squinty system is cost effective and has reused some of the materials to complete intelligent ground vehicle competition. Below table 1 is the total cost of materials required for building Squinty, which includes using last year materials, which are highlighted in red. Since these . Changes in red that is taken out of the total cost.

Part	Unit Cost	Quantity	Total Cost	Cost to Team
<b>Locomotion:</b>				
<b>() Briggs and Stratton E-Tek Motor</b>	<b>(\$400.00)</b>	<b>2</b>	<b>(\$800.00)</b>	<b>(\$400.00)</b>
NPC-02446 Motors	\$72 .00	2	\$144 .00	\$144.00
NPC-Gearset 4:1	\$95 .00	2	\$190.00	\$190 .00
RoboteQ AX2550 Motor Controller	\$495.00	1	\$495.00	\$495.00
E-Stop Circuit & High Power Relays	\$300.00	1	\$300.00	\$300.00
Dual Pro LS 2200 Deep Cycle Battery	\$133.00	1	\$133.00	\$133.00
Cherry GS100902 Geartooth Hall Effect Sensor	\$40.00	2	\$80.00	\$0.00
60 Tooth Sprocket, #35	\$29.68	2	\$59.36	\$59.36
1" Axle Pillow Block Bearing	\$12.95	4	\$51.80	\$51.80
1"x1" Low-Carbon Steel Box Tubing (per foot)	\$2.00	25	\$50.00	\$0.00
<b>() 4 x 10" Knobby Hand Truck Tires</b>	<b>\$36.00</b>	<b>1</b>	<b>(\$36.00)</b>	<b>(\$36.00)</b>
Golf Cart Tire 16.2"	\$48.00	4	191.96	\$191.96
<b>() Drive Wheel Hub</b>	<b>\$14.99</b>	<b>2</b>	<b>(\$29.98)</b>	<b>(\$29.98)</b>
Wheel Hub	\$20.00	4	\$79.96	\$79.96
15 Tooth Sprocket #35	\$7.43	2	\$14.86	\$14.86
#35 Riveted Roller Chain, 3/8" Pitch	\$2.21	6	\$13.26	\$13.26
1/4" Plywood (24" x 24" sheet)	\$3.49	2	\$6.98	\$6.98
<b>Sensing:</b>				
Unibrain Fire-I Board Color Cameras w/ 2.1mm Lens	\$139.00	2	\$278.00	\$278.00
GPS Module	\$200.00	1	\$200.00	\$200.00
Brainstem GP Microcontroller	\$81.00	2	\$162.00	\$162.00
Serial to USB Adapter	\$40.00	1	\$40.00	\$40.00
Devantech IIC Compass Module	\$51.00	1	\$51.00	\$51.00
Misc Wire and Wiring Hardware	\$50.00	1	\$50.00	\$50.00
Component Boards and Enclosures	\$50.00	1	\$50.00	\$50.00
<b>Control:</b>				
Dell Inspiron 1150 Laptop	\$989.00	1	\$989.00	\$989.00
		Total:	\$2,810.24	\$3,034 .00
		Old Total:	<b>\$3,890.00</b>	<b>\$3,360.00</b>

\*new items

**Table 1: Cost of materials for Squinty**

**()old items**

As the table shows, the total cost of the vehicle decreased, mainly because we used less powerful motors. This is not the total cost spent developing the current Squinty Vehicle, since some materials were reused or replaced with a similar type.

## **5. Last Remarks**

Squinty was designed to be inexpensive, but still capable of competing in the autonomous and navigation challenges in the 14<sup>th</sup> Annual Intelligent Ground Vehicle Competition. While the Initech team might be small compared to others, we still managed to acquire the skills, knowledge, tools, and funding required to complete the task at hand. We would like to extend our gratitude to the faculty of UMBC's CSEE department, as well as the IEEE Baltimore Branch, without whose help this project would never have gotten off the ground.

**Appendix A: Faculty Advisor Statement Sign-off**

Faculty Advisor Statement Sign-off

By signing below, I am certifying that the engineering design in this vehicle by the University of Maryland: Baltimore County student team 'Initech' has been significant and equivalent to what might be awarded credit in a senior design course.

Comments:

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Professor David Bourner

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Date

Computer Science and Electrical Engineering Department  
University of Maryland: Baltimore County