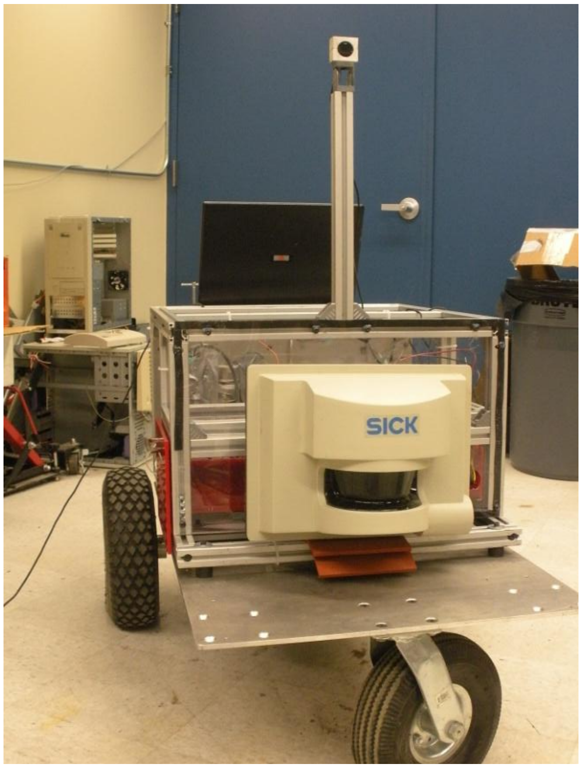
Stony Brook University
Robot Design Team

Intelligent Ground Vehicle Competition 2011

TINA 2.1
(Terrain Independent Navigation Automaton)



Team Members

President: Sebastian Cocioba
Vice President: Pias Malaker
Treasurer: Sagirah Elson
Secretary: Mika Lai

Electrical Engineering Team Lead: Sebastian Cocioba
Electrical Engineering Team Members: Asheik Hussain, Frank Pernice, Marek Roszko

Mechanical Engineering Team Lead: Phillip Prestia
Mechanical Engineering Team Members: Sagirah Elson, Mika Lai

Software Engineering Team Lead: Daniel Zeidler
Software Engineering Team Members: Sebastian Cocioba

Faculty Advisor Statement

I certify that the design and creation of TINA 2.1 has been significant and is equivalent to what might be awarded credit in a senior design course.

Professor Yu Zhou
Department of Mechanical Engineering
Stony Brook University

05/09/2011
Date

Changes to Robot:

Software:

- Improved line-tracking and Global Positioning System Capabilities

Mechanical:

- New Battery Box
- Removed GPS and Compass Tower

Electrical:

- Rewired system for safety

1. Introduction

Introducing TINA 2.1, the latest autonomous ground vehicle engineered by The Stony Brook University Robot Design Team. TINA 2.1 (Terrain Independent Navigation Automaton) was designed to meet the criteria of the 2011 IGVC competition. TINA 2.1 has been primed for autonomous navigation through various obstacles, line-tracking and waypoint GPS navigation. TINA 2.1 has been a collaborative effort of a team of undergraduate students from Stony Brook University. These undergraduate students are a collection of diverse majors including Mechanical, Biomedical, Electrical and Computer Engineering and Mathematics, Biology and English. This diversity has allowed for different perspectives in the collaborative process of the designing and construction of TINA 2.1. TINA 2.1 consists of features used previously in TINA 2.0 (2010) and TINA (2009), with improvements to accommodate for the weaknesses witnessed. These improvements were carefully analyzed and tested repeatedly to ensure the best improvements for TINA 2.1.

1.1 Innovations

The most notable improvements for TINA 2.1 are modifications made to previous enhancements made for TINA 2.0. The significant mechanical innovation was the decision to use a single caster wheel as opposed to the two caster wheel system from prior years. Furthermore, the battery box has been completely rebuilt to allow for more lithium ion batteries to draw more current when necessary. The new battery box was made from acrylic with garage insulation used on batteries, and laser cut to fit perfectly into the chassis of TINA 2.1. The acrylic box was mounted onto the bottom to allow for maximal vibration damping and to ensure that the batteries do not fall out as TINA runs the course. The GPS and compass tower have been removed to make TINA a more compact ground vehicle. In the electrical portion, the use of quick connects allowed us to improve the wiring system of TINA 2.1 to ensure safety and provide a neat, easy-to-follow wiring schematic. The use of the blinking lights will allow us to see how TINA 2.1 is responding over time. Vast improvements have been made to the line-tracking software and GPS navigation. The use of Open Cv allowed the use of better optical analysis, such as the filtration of glaring sunlight to improve the line-tracking application.

1.2 Design Process

This robot was designed, built, and tested under the framework of a five stage process. The first step is research, in which knowledge from past experience was combined with the given set of rules to define goals and requirements. The second step was the conceptual design phase in which all possible configurations were generated and evaluated. For the third phase, detailed design, the chosen configuration was elaborated and exact measurements calculated. Autodesk Inventor was used along with relevant equations to design the full system as well as old-fashioned pencil and paper. The fourth step involved fabricating the physical system and writing the code needed to run TINA 2.1. The last step was to test and debug the system. Since this robot first appeared in the IGVC in 2010, this year the focus was on steps 3 through 5. Testing would portray flaws in the system that were revised through an interactive process. Schematically, this is shown in the following figure:

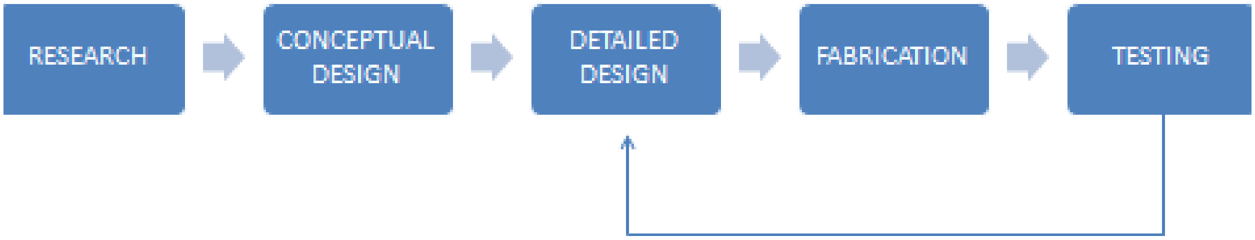


Figure 1.1 Concept map of design process.

1.3 Team Structure

The president handles administrative duties and keeps track of overall progress, while the vice president manages individual projects and safety. The treasurer balances the accounts and purchases needed supplies, while the secretary takes care of paperwork and notifications to the team. The public relations team handles the team's image and recruitment activity.

The team is divided into three sub-teams: Electrical Engineering, Mechanical Engineering and Software Engineering. An individual member usually belongs to one of these teams, depending on the particular member's skills and inclination. Each team is assigned to design a subsystem within the robot to perform specific functions. The sub-team leaders meet periodically to ensure that each design can be integrated into the robot and coupled to the other subsystems.

2. Mechanical Engineering

2.1 Battery Box

This year's battery box contains 10 lithium ion batteries. The box is made of acrylic, laser cut to fit exactly the width of the robot. This box slides in and out of the robot body on rails glued to the base of the robot. The glue was specifically designed for joining metal to metal, which ensures a strong bond and prevents any corrosion from the glue. This rail system makes it easier to replace charge and repair the batteries or connections.

2.2 Weather Proofing

The weather proofing is made of polycarbonate plastic and old computer cases, which completely encase the robot. The polycarbonate plastic was purchased, but the old computer cases were donated and a way to recycle. The top of the robot can be opened by a piano hinge on the back of the robot. Caulking, which can easily be torn off and reapplied, seals the edges of the robot to keep our electronics dry.

2.3 Laptop Enclosure

The laptop controlling the robot is located in the back of the robot. The door containing the laptop is hinged on the bottom to fold down, and two legs can be attached to the corners to act as a table for on-the-spot debugging.

2.4 Design

This year we removed the unwieldy tower of the robot after we discovered it was unnecessary for either the GPS or the compass to function properly. The frame of the robot is based on a modular design to make modifications easier. Build in an upper part containing all electronics and the laptop and a lower part containing the motors and gearboxes, each half of the chasses is separated by rubber vibration dampeners. The overall effect is lower vibration and less sudden movement on the cameras.

3. Electrical Engineering

3.1 Sensors

The main sensory components comprised of the SICK LMS 210, the Ocean Server 5000, and the Raven Invicta 115 GPS. The SICK LMS 210 is the LIDAR system which has 180 degree forward obstacle recognition. The LIDAR's main purpose was in the main obstacle avoidance sensor. The Ocean Server 5000 is the digital compass used to determine the current position and location of TINA. The Raven Invicta 115 GPS was the GPS system integrated into the navigation of TINA. This GPS module aids in determining the position of TINA and in the overall autonomous navigation.

3.2 Motors

Two QuickSilver Controls (QCI) servo motors and matching motor controllers are used for the primary locomotion of TINA. The servo functionality of these motors and their controllers allow us to have motor platform that we can easily interface with and control without needing additional programming to control the motors. The controllers allow us to simply send commands in order to move as desired with a good degree of precision. Furthermore, the controllers serve the purpose of bypassing additional programming which saves time that would otherwise have been wasted in development and testing.

3.3 Wiring

All wiring was done using 16 gauge insulated copper wire due to concerns of current draw of approximately 20 amps at max torque/load from the motors. The wires were intertwined with the Molex Quick disconnects for simplicity. These Quick disconnects are used between interconnections of different circuit elements such as sensors, motor controllers, etc. Two large heatsinked resistors are attached between the chassis and the motor ground portion as a safety precaution in case of electrical failures that may otherwise send current flowing into the chassis.

Main motor power runs through a 25 amp circuit breaker while the LIDAR runs on a smaller 5 amp circuit breaker. A DC/DC converter module is used to provide a stable and efficient 5V and 12V power source from the main power supply over a variable range of input voltage due to the expected voltage drop from discharge of the batteries. The 5V source is mainly used to power the digital compass.

The main power supply consists of 10 11.1V, 13amp-hour(Ah) Lithium-Ion batteries which were custom ordered from Tenergy. The batteries are connected in sets of two in series and then these 5 sets are connected in parallel to provide a roughly 22.2V source (figure 1). The voltage drop due to discharge of the batteries has been observed to be minimal enough to allow operation of the motors for long periods of time. The motors, however, require a consistent supply of voltage greater than 20V, otherwise there will not be enough torque generated to maneuver. The voltage of the batteries is applied directly to the motors and LIDAR unlike the compass. Once again, these components run through the circuit breakers to increase the safety measures of TINA. All electrical components are grounded to the chassis of TINA in specific areas to provide the same common ground for all electrical elements and a discharge path directly to earth ground if any serious issues may ever arise.

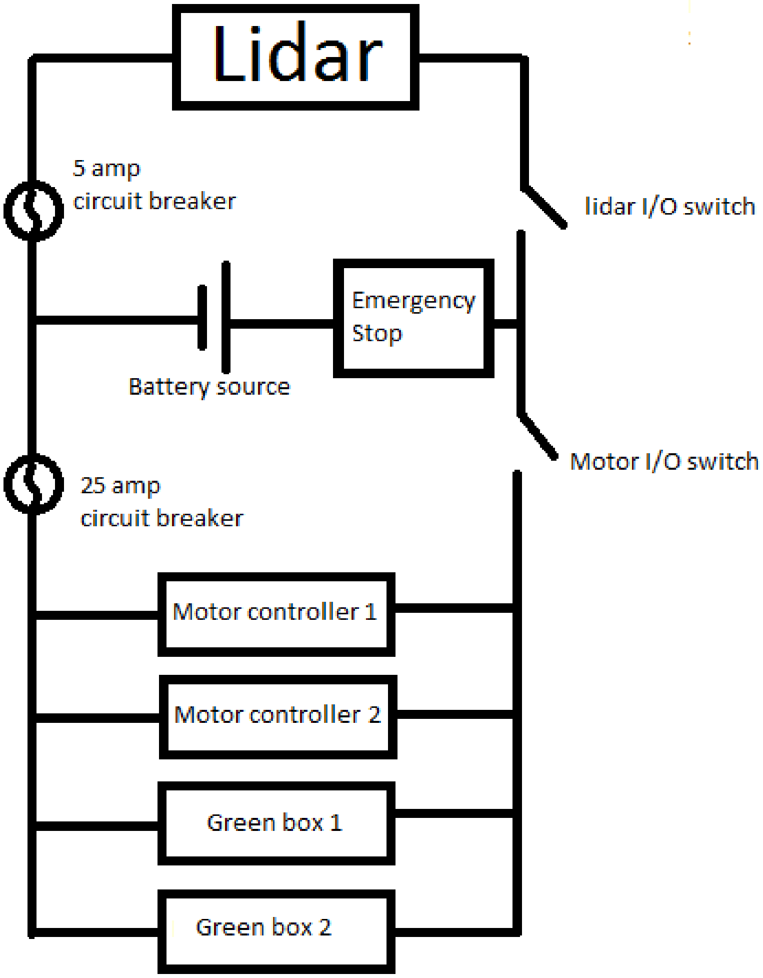


Figure 2: Batteries that we used were 11.1v at 13 amp hours each. Two batteries were connected in series which formed a battery cell. 5 battery cells were connected in parallel. The emergency stop is wirelessly controlled by a car remote with a receiver. The remote sends a coded signal to the receiver and flip flops are used to filter out the signal. Then a half-h driver will trigger an automotive relay switch which breaks the power to the main circuit. A linear regulator (lm7805)

will be used to provide a constant stable 5 volts to the emergency stop circuit. A debounced pushbutton will be used as the onboard emergency stop switch.

4. Software Engineering

This year's robot is utilizing the OpenCv computer vision library and the C# programming language to achieve the required functions for the competition. The motor controllers will be sending feedback from the motor encoders, as well as other data like temperature, voltage, current draw, and torque in the form of serial strings back to the on-board laptop for interpretation and processing. The GPS and LIDAR will also send serial string data and all the devices will be on separate processing threads to ensure truly synchronous processing of all data in real time.

The lane tracking algorithm used in TINA 2 is a multisensory approach. A webcam is used to track the white lines, a SICK LMS 221 LIDAR system is used for physical obstacle avoidance, and a Raven Invicta 115 GPS system is used for the waypoint navigation challenge. The webcam sends a real time (30fps) video feed to the onboard laptop where it is further processed. A blur filter is applied to create a uniform color distribution across the image which removes noise caused by small blocks of pixels which contain the desired color appearing randomly throughout the image. Water drops on grass can produce a reflection of light from the sun to be picked up by the camera as white which is the color we are searching for. Also, depending on lighting conditions, and grass color variations, the RGB values of the pixels change thus one would require a reduction of the variation in order to quickly detect the desired color.

Then, a RGB channel filter is applied which removes Red and Green from the desired color spectrum. This allows the white lines (whose RGB spectrum is around 255 for all three channel byte values) to be picked up on the blue channel. Since grass is mostly shades of greens and browns (Red+Green), the line tracking algorithm will only “see” the white lines against a black background. Then the picture is gray scaled to form a 16-bit black and white image. This is for optimization purposes since there is no need of a color image after filtering. Black and white images can be processed faster than color due to the smaller amount of data contained in each pixel. The next step is to shift the frame of reference to a “bird’s eye view” of the obstacle course. Since the camera is pointing to the ground from a known point and angle, an OpenCV projected plane matrix transformation can be applied. A calibration sequence was coded which took a picture of an object (black cardboard square) of known dimension and distance away from the robot, and its corner points coordinates (both in X,Y Cartesian coordinates in the camera image field of view and an X,Y of the actual distance from robot to the specified point on the calibration object) were applied to a matrix whose parameters were predefined in the OpenCV library Matrix class. The matrix was then transformed so that the field of view was now in such a way that the image appeared to be that of a top-down perspective rather than a field of view at an angle of about 45 degrees downward onto the course. This aids the next step of the program which utilizes the LIDAR system.

A LIDAR system is a far-infrared optical laser range finder. It uses a laser beam and a rotating mirror to echo light beams to the surrounding environment with a usable range of 20 feet with a field of view of 180 degrees at 0.5 degree intervals with a resolution of 1cm. The beam sent out bounces off of objects and is returned to the device. The travel time is computed and a serial stream of angle and distance data points is sent back to the onboard laptop computer. The LIDAR output can be interpreted as a polar coordinate system of 360 data points and is can be visualized as a top-down perspective mapping of nearby objects. This data is then overlaid onto the bird's eye view white line image coming from the webcam. Since the LIDAR can only see physical objects at a fixed height, a composite image is formed using the data points from the LIDAR and the camera white line data points thus enabling the navigational program to find the best route between obstacles given the white lines and a detected "physical barrier" that the robot cannot pass.

A GPS "blacklist" was also created so that when an obstacle is detected by the composite sensor system, the GPS coordinates are calculated for said obstacle and is stored in memory for a short period of time (roughly 30 feet of travel distance) in order to assist the robot if the situation calls for a reversal of a selected path. A virtual map can then be plotted where the newly discovered obstacles are drawn with good accuracy onto the navigational "field of view". This does not mean that the robot has any prior knowledge of the course but rather a post-detection memory bank of newly discovered obstacles.

5. Safety Components

5.1 Wireless E-Stop

The E-Stop was based off a paired car remote receiver/transmitter.

It works beyond the required 100 feet range. Pressing any button on the e-stop remote will trigger a signal output on the receiver which triggers the activation of a power relay which will trip the power to the motors and the rest of TINA.

5.2 Safety light

State of the safety light is read from the I/O port of a motor controller due to simplicity and desire to avoid more computer interface wires. This I/O port is based on 5V logic and is easily set by commands sent to the controller in normal operation.

Default state of the light is a solid color; otherwise it will be blinking given the correct I/O port output.

Blinking circuit consists of a LM555 timer in a stable mode designed to output roughly 41 pulses per minute. The 555 timer output is connected to an AND gate to compare with the current I/O port state and then the output of the AND gate connected to an inverter. Thus when the I/O port is set to 1, the pulses will pass through the gate and inverter to a transistor to switch the power to the light source on and off repeatedly. Otherwise the AND gate will default to the zero state which is then inverted to 1 to cause the transistor to let power to flow to the light source uninterrupted.

6. Cost Breakdown

Component	**Quantity**	**Actual Cost**	**Cost To Team**
SICK LMS 221 LIDAR	1	5,421.43	0.00
Tenergy Lithium-Ion Batteries	10	1010.00	1010.00
24 V DC motors	2	unknown	0.00
Raven Invicta 115 GPS	1	1,359.00	0.00
OceanServer 5000 Compass	1	$400	$400
ZT Group Laptop	1	1099.99	0.00
AX1500 Motor Controller	1	300.00	300.00
Extruded aluminum		300.00	300.00
Microsoft LifeCam Cinema camera	2	79.98	79.98
Smart charger	6	185.93	185.93
Polycarbonate 1/16” thick		122.80	0.00
10” castor wheels	2	32.99	0.00
14” drive wheels with split rims	2	69.96	0.00
LIDAR mounting bracket	1	76.50	0.00
Commando EZ-2500 wireless transmitter	1	69.99	0.00
Electronic components (wires,		20.00	20.00

fuses,etc)			
4 port USB hub	1	11.99	0.00
Serial port to USB cable	1	8.99	0.00
Red diameter emergency button	1	3.00	0.00
Sheet Aluminum	2	300.00	300.00
Miscellaneous Hardware (Bolts, lubricant, nuts, etc)		100.00	100
Voltage Clamp	2	227.80	0.00
Rubber Dampeners	2	40.00	40.00
TOTAL		**$11,240.35**	**$2,735.91**