

Seventh Annual International Ground Robotics Competition Design Report



KENNY

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1. Introduction

The purpose of the Autonomous Vehicle Project is to design and construct an unmanned vehicle for entry in the International Ground Robotics Competition. This vehicle has been nicknamed Kenny by the team, after the South Park character, and is the first entry to be made by the University of Maryland, College Park.

The design team currently consists of six undergraduate students, three from computer science, two from electrical engineering, and one doubling in both mechanical and electrical engineering.

This document is about the overall design of Kenny. Several systems are not yet completely functional. They will be treated as if everything is fully operational, where applicable.

2. Electrical

2.1 Power

Six 12-Volt batteries are used to power all the electrical devices on it. Four of the six batteries are dedicated to the drive system alone. Since the drive amplifier can draw 50 Amps at 24 Volts, it was decided to place two batteries in series in parallel with another pair of batteries that are also in series. This is shown in Figure 1 below, for clarification. By placing them in parallel, 25 Amps is drawn from each pair of batteries at a time instead of 50 Amps from a single pair. Therefore, they can last longer before needing replacement and recharging.

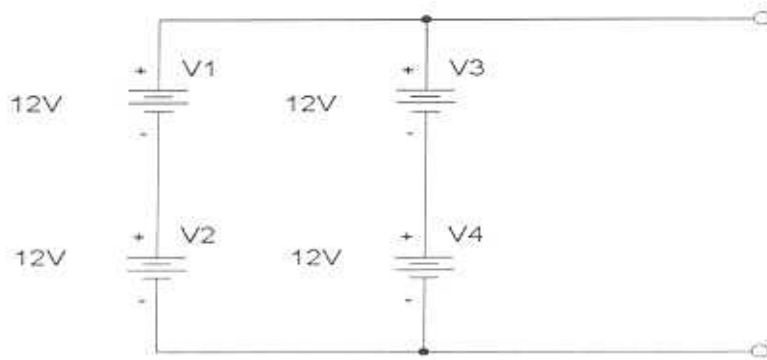


Figure 1. Battery Wiring for Drive Amplifier

The remaining two batteries are also connected in series, and provide power to the inverter, which in turn powers the onboard computer. The battery connected to the ground terminal also supplies power for the remainder of the other systems, the most notable being the steering stepper motor controller. Since the controller requires not only +12 Volts, but +5 Volts as well, the battery is connected to a voltage regulator that supplies the necessary voltage. This is shown in Figure 2.

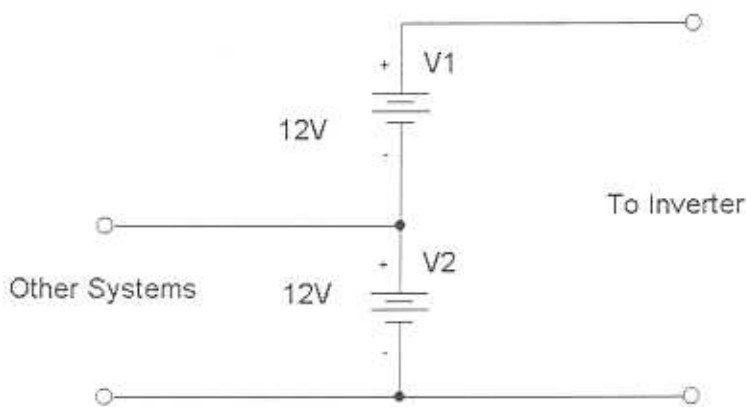


Figure 2. Battery Wiring for Remaining Systems

There are six spare 12 Volt batteries that are used as replacements to the original six, should any or all of them become drained and in need of recharging. These spares are not located on the vehicle, but replace the low batteries on board as necessary. Once the vehicle becomes operational (even minimally), endurance tests will be run to determine the average life of the batteries, as well as which become depleted first.

2.2 Computer

The computer is a dual Pentium, 100 MHz system, but only one processor is installed currently. The reason a dual processor computer was selected is because Dr. Hendler (Professor, Computer Science, University of Maryland, College Park) recommended it to the team as a good way to increase the processing power of the computer. A single processor is currently used instead of two due to lack of funding; money had to be disbursed to other parts of the project. When the project next receives its budget for next year, one of the top priorities will be the purchase of the second processor.

The computer uses a Matrox Meteor II frame grabber for image capturing from the camera. This particular frame grabber was chosen because it could handle color images and it processes images quickly.

3. Mechanical

3.1 Vehicle Layout

A riding lawn mower is used as the base frame for the vehicle because it greatly simplifies much of the mechanical design and construction. It already has drive and steering mechanisms in operation, as well as a good amount of mounting space and structure for adding on the various other systems (i.e. - the computer, batteries, camera, etc.).

The vehicle itself is divided into different sections. They are the electronics bay and computer, camera stand, battery mounts, and the outer shell. These are shown in figures 3 and 4 below.

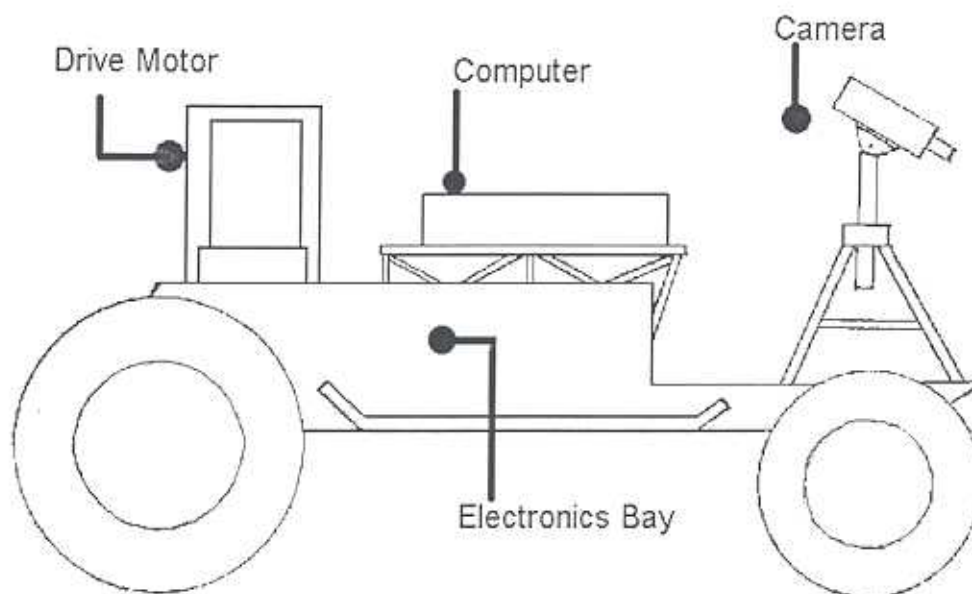


Figure 3. Side View of Vehicle Layout

Please note that the outer body shell is not shown. The control panel, which is located above the computer, is also not shown because it is mounted to the shell.

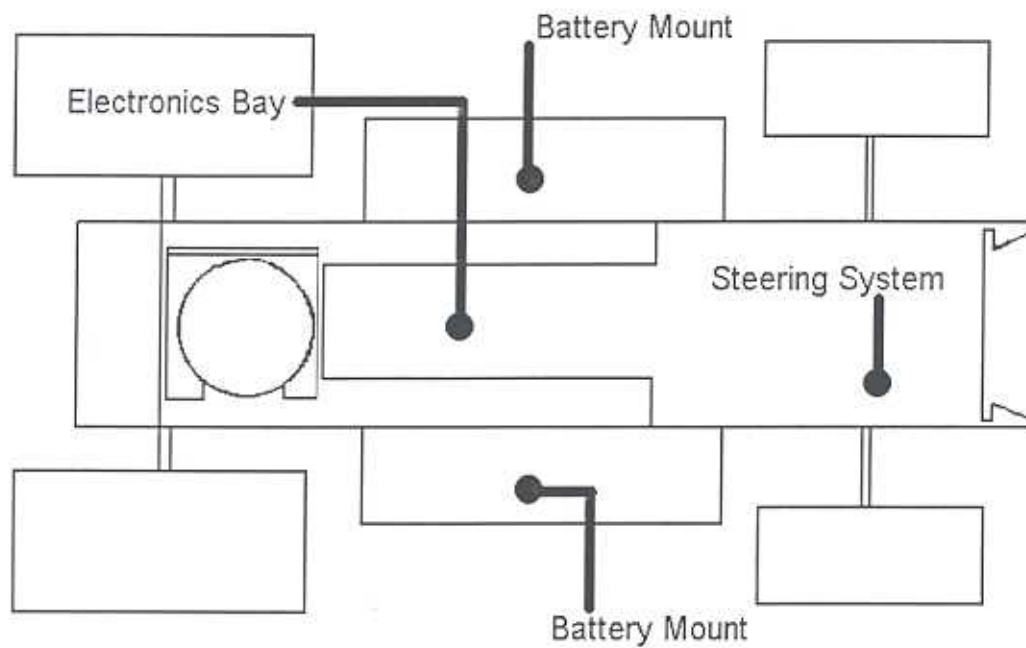


Figure 4. Overhead View of Vehicle Layout

By sectioning the vehicle layout into explicit areas, it made it simpler to place the components. The different section locations for each system were chosen for either their proximity to certain devices (such as the drive motor to the rear wheels or the steering system to the front wheels) or for the ease and frequency of access (such as the batteries).

In the center of the frame is the electronics bay. The bay houses all the electronic parts of the vehicle, including the drive motor amplifier and controller, the steering motor controller, inverted, and the emergency stop circuitry. The computer is mounted on a platform above the bay because it is too large to fit inside it and it also makes it easier to access the ports when needed (for updating the programming or systems check). Just above the computer is the control panel, housing the warning LED's, battery relay switches and relays, fuses, and connector ports (video, keyboard, etc.). The only switch

not included as part of the control panel, is the emergency e-stop that is placed in the rear of the vehicle. The fuses and relays are accessible through the control panel to make it easier for replacement.

On each of the side board runners, three batteries are placed, for a total of six. Each group is secured down with pieces of aluminum U-channel bolted to the frame on both the tops and outer sides of the batteries (the sides facing to the outside of the vehicle). By placing them on the outside runners, it makes it easy to quickly replace any drained batteries.

The camera is mounted in the front, approximately 3 feet above the ground. The mount itself is designed to allow the camera's height and tilt angle to be adjusted, so that optimal viewing can be achieved. The height can be adjusted by +/- 6 inches, and the tilt angle can be adjusted from 0° (looking straight ahead, not down at all) to 45° down.

The whole vehicle is covered with several molded sheets of Lexan®, for protection of the interior equipment against rain or inclement weather. Removable panels are included on the sides of the vehicle to enable easy access to the batteries, as well as one for the control panel. Also, the underside of the vehicle also has several flaps placed around openings to protect against traveling through mud and rain. Two ventilation fans are used to help dissipate heat buildup.

3.2 Drive System

The drive motor is a DC brushless 24-Volt motor. It is mounted on the back of the vehicle, directly above the rear wheels differential. It directly drives the differential gear, with no speed reduction required. The drive controller requires a feedback encoder

for proper operation. An optical encoder is connected to the left rear wheel, via a pair of spur gears. One of the gears is placed on the encoder shaft, and the other is mounted directly on the rear axle.

3.3 Steering System

The steering motor and linkage is in the front of the vehicle, attached to the front right wheel. The steering motor is a 5-Volt stepper motor, which houses an ACME lead screw. The stepper motor drives the lead screw in and out, providing linear motion. The lead screw then acts on a lever attached to the front right wheel, enabling Kenny to turn in any given direction and holding it.

4. Software

4.1 Development Software

The computer uses Windows NT v4.0 as it's operating system. This allows the computer to multitask all of its programs, and it is better suited for real-time operations than other operating systems.

All the software that was developed by the team was written using Microsoft Visual C++ Developer's Studio™. By using C++, all the software could be multi-threaded, enabling the computer to process images, compute navigation directions, and control the steering and drive system in parallel.

AutoCAD™ and Pro/Engineer™ were used in the design of the mechanical systems, as well as the component layout. P-Spice™ was used in the circuit design and simulation.

4.2 Image Analysis

The image analysis starts with the camera and the frame grabber. The frame grabber captures a color image from the camera, and saves it as a bitmap. The bitmap file is then examined and flood-filling the image identifies the obstacles and lines. The identifying colors are picked out, and converted to neutral colors (colors that aren't normally observed in any image, such as purple or neon green) to ensure that they aren't confused with anything else.

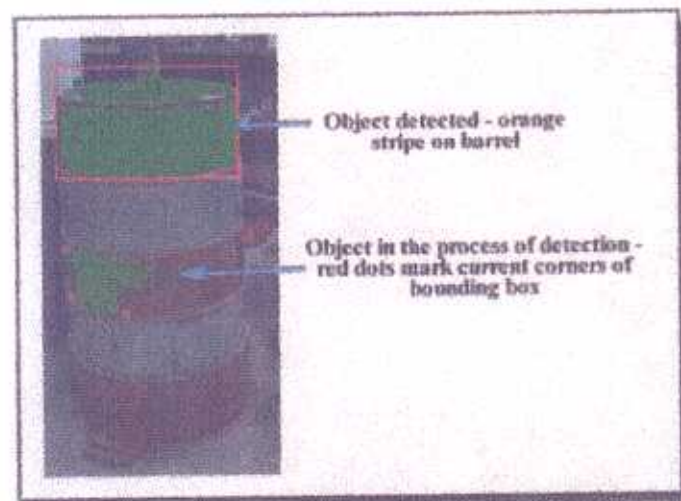


Image 2.1, Floodfill Routine Example

The rest of the image is ignored, and changed to black. The identifying colors are orange for the construction barrels, one range of white for the paint buckets, and a second range of white for the boundary lines. These colors can be adjusted manually, to compensate for different lighting conditions. Also, once the program has found a continuous block of pixels (any qualifying pixel that touches another qualifying pixel on one of its four sides) that match a given color range of an obstacle, the block's width, height, and location in the bitmap are recorded. Since the boundary lines typically run

from the top of the image to the bottom, a limit on the height of each line block is set, so that they can be handled more easily.

A second layer of filtering is performed by examining the height and width of each potential obstacle. Since the buckets and barrels are of known dimensions, any obstacle that doesn't have close enough height/width proportions is ignored.

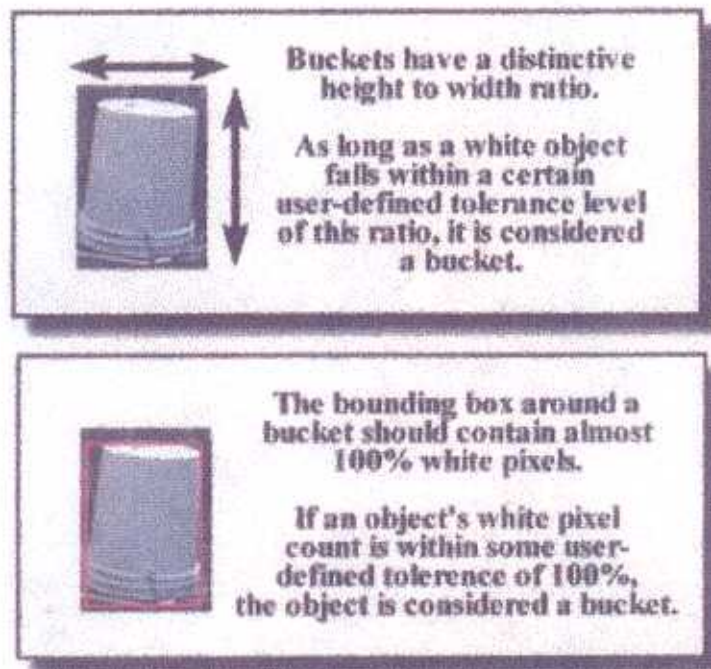


Image 2.2, Pattern-Matching Routine Example

The next step in the analysis is the determination of the relative distance to each bucket or barrel; the lines are ignored for this part. This is done by using the height and width values for each obstacle that was recorded, and comparing them to a set of pre-recorded values. Previous to the vehicle's run, a list of reference obstacles is generated by taking images of buckets and barrels at fixed and known distances. Since each object's dimensions is in proportion to its observed distance, the relative distances can be computed.

The distance to the lines is not strictly determined. The only criterion in handling a line is the relative proximity of the line to the vehicle. Since the height of each line block is limited, only the width of the boundaries is of concern. Also, since the width of the track lines is not currently known, and it may not be constant, the position of the lines in the image is used instead of size. The proximity to either line can be determined from its position in the image. The closer to the middle of the image, the closer it is to Kenny. The closer to the edge, the farther away it is. But since the course will have turns, only the lower parts of the lines are used. Again, by making sure that the vehicle travels neither too far nor too close to either line, it can stay inside the course even when one of the lines is absent.

The image analysis program then hands these objects, their positions, and distances to the navigation program. It also passes along the relative positions of the track lines as well.

4.3 Navigation and Path Planning

The navigation program takes a list of objects and lines and computes a direction to move in. Of all the objects identified, the closest and farthest objects are picked. The farthest object becomes a target the vehicle aims for, while the closest obstacle becomes the one thing the vehicle tries to avoid. If there is only one object, it becomes the one to avoid, and the program picks the farthest point it can see, that is still between the course lines. If there is no obstacle, then it still picks the farthest point as before, but doesn't need to pick a close object to avoid.

Instead of trying to perform processor intensive computations of exact steering angles and trajectories, Kenny uses the simple method of turn left, turn right, or straighten the wheels. Therefore the vehicle has only three steering directions. This is not a handicap but an advantage. We perform the image analysis and path planning routines several times per second. Hence, the path is being adjusted many times per second yielding a fine turning radius with little overhead in the path planning algorithm.

The first step is to take the target object, and determine which direction would bring Kenny closer to it. This is done by dividing the camera image into five vertical sections, all the same width. The section the target lies the most in that becomes the direction to move in. The closest obstacle modifies this direction, if present. By using the same five sections, and the object's distance, the vehicle's course is adjusted so that it will move to avoid it. The closer the obstacle, the more weight is given to moving away from it.

The course lines are ignored, for the most part. Only when a line is observed to be too close or too far away will the navigation program take it into account. If a line should become too close or too far, a second modification to the vehicle's course to compensate and move it either farther or closer, as necessary.

Kenny's velocity is determined by the proximity of the closest obstacle or line to it. The closer an object is to the vehicle, the slower it travels. This is to ensure that Kenny will more deftly avoid obstacles or crossing course lines.

5. Design Team

Name	Major	Year	Responsibility
Jarriel Cook	Electrical Engineering	Senior	Administration, Drive System
Pete Guion	Electrical/Mechanical Eng.	Senior	Mechanical Design, System Interfacing
Josh Guzman	Electrical Engineering	Senior	Power Systems
Brian Renn	Computer Science	Senior	Image Analysis, Computer Systems
David Siegel	Computer Science	Junior	Navigation, Path Planning
Jeff Mason	Computer Science	Junior	Navigation, Steering