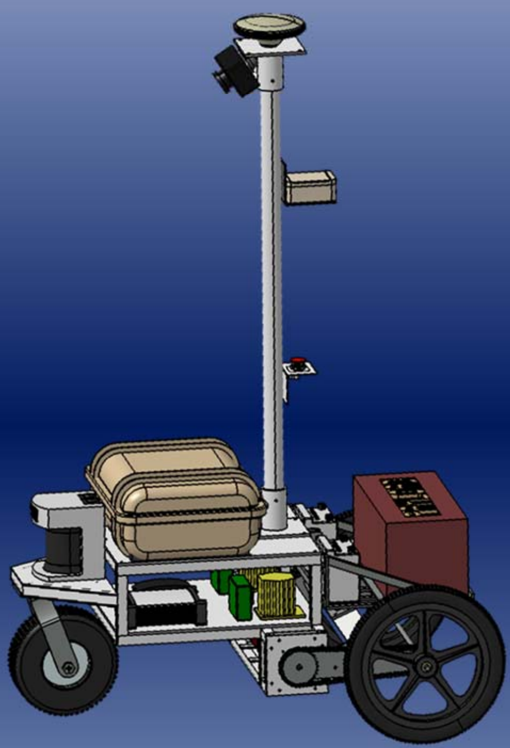
EMBRY-RIDDLE
AERONAUTICAL UNIVERSITY

Presents

Reagle V



Team members:

William Meng, Jamal Burch, Megan Scheppa, Randy Breingan, Gregg Leonard, Matt Standifer, Alecia Hurst, Joseph Pavicic, Duncan Miller, Krishna Ajmeri, Michael Mikloucich

Faculty Advisors:

Charles Reinholtz, Patrick Currier, Eric Coyle

Faculty Advisor Statement: I certify that the engineering design of the vehicle described in this report, Reagle V, has been significant and is equivalent to that required in a senior design project.

1 INTRODUCTION

Reagle V is the fifth iteration of the Reagle platform, a three wheeled differentially-steered robotic vehicle. Reagle V has been improved both mechanically and electrically to be more reliable than its predecessor, Reagle IV. It also has a completely reworked software algorithm to handle the new challenges of the course.

2 DESIGN PROCESS

Although Reagle is not a new platform, a seven step design process (Fig. 1) was still used to determine if changes were needed and the extent to which they were needed. The customers are the IGVC competition judges, the senior design professors, and future team members. With those customers in mind, new specifications were set this year to not only meet the new minimum standards, but also to improve upon the previous year's platform.

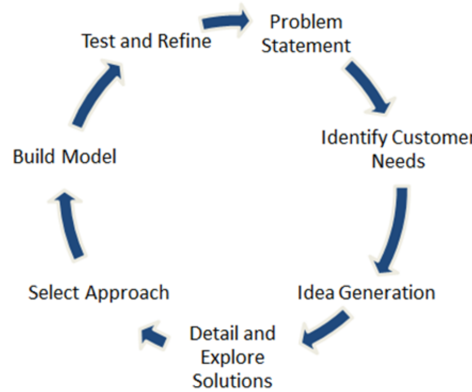


Figure 1: Design methodology

The IGVC competition has changed significantly as the layout of the course was modified by combining the autonomous and navigation challenges, which doubled the length of the course and the chance for critical errors. The green flags were changed to blue, and their arrangement was made much more difficult. More complex traps such as dead ends were added to the new course. Speed was also a priority now that other vehicles could pass.

In response to the change in needs, ideas were generated to address each item. It was determined that software would be the main focus of this year's team since the previous software had been outgrown by the changes in the course.

Through an iterative process of selecting an approach, testing, and refining, the algorithms that will perform at competition have been thoroughly evaluated to ensure they will meet the demands of the competition course.

In order to make certain that changes were implemented in a timely manner, a Gantt chart (Fig. 2) was used to create a timeline of expected progress and milestones. These goals were checked weekly and adjustments were made accordingly.

Build CAD Models	4 days	Thu 10/13/11	Tue 10/18/11
Refine Model	4 days	Wed 10/19/11	Mon 10/24/11
Midterm Presentation	0 days	Wed 10/19/11	Wed 10/19/11
Complete Model Design	0 days	Mon 10/24/11	Mon 10/24/11
Build Model	**41 days**	**Mon 9/26/11**	**Mon 11/21/11**
Build Mock Payloads	8 days	Mon 9/26/11	Wed 10/5/11

Figure 2: Gantt chart snapshot

2.1 Improvements

Below is a summary of major changes this year, and each is discussed in more detail in its respective section.

- Mechanical: Trailing arm suspension modified to reduce load on gearhead
- Electrical: Entire vehicle rewired and new connectors installed
- New Sensors:
  - Novatel SPAN DGPS
  - GoPro camera for machine vision
- Software: completely overhauled algorithms
  - Combined autonomous and navigation code
  - New flag detection algorithm
  - New dead end algorithm
  - Refined line detection and obstacle avoidance algorithms

2.2 Innovations

Gap Selection Path Planning Algorithm

Reagle has traditionally used a purely reactive obstacle avoidance algorithm, which results in suboptimal paths that resemble straight lines towards the waypoint until the vehicle is in close proximity to an obstacle, shown as the red path in Fig. 3. This new path planning algorithm creates an instantaneous map of obstacles within 15 meters of the vehicle and selects a heading towards gaps on the side of or between obstacles (green in Fig. 3), thereby taking the optimal path.

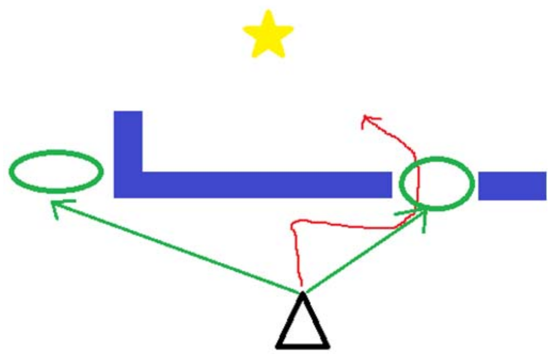


Figure 3: Gap selection path planning

Matlab Data Log Replayer

Another new innovation this year is an intuitive, graphical data replay program that shows the simulated motion of the vehicle, GPS path history, obstacles, target waypoint, and a customizable informational display (see Fig. 22, section 5.8). This program helps tremendously in analyzing sensor and algorithm raw information in an easy to use manner, as opposed to simply reading lines of numbers. We plan to improve this program in the future to read simulated data and show predicted vehicle behavior.

Novatel SPAN GPS System

New this year is the top-of-the-line Novatel SPAN, or Simultaneous Position and Attitude Navigation, system. This GPS fuses IMU and GPS measurements with a Kalman filter, so that continuous, inertial measurements can be made at very high speed, up to 100 Hz. This occurs even if the GPS signal is lost or obstructed, next to a building or under a bridge, for example. Having precise localization at all times is critical to successful autonomous mapping and performance, and the SPAN system is one way that we can achieve this goal.

2.2 Vehicle Cost

Table 1: Reagle V costs

Reagle Component	Quantity	Retail Cost	Team Cost
Sensors & Electrical			
APlus Ruggedized Computer	*1*	*$10,000.00*	*$0.00*
Novatel SPAN DGPS and Antenna *(new)*	*1*	*$25,000.00*	*$25,000.00*
Sick LMS-291 Scanning Laser Range Finder	*1*	*$5,930.00*	*$2,000.00*
GoPro HD Hero Camera *(new)*	*1*	*$200.00*	*$133.00*
Sparton SP3004D Digital Compass	*1*	*$650.00*	*$0.00*
Gearmo RS-232 Serial to USB Converters	*1*	*$44.00*	*$44.00*
Custom In-House Power Distribution Board	*1*	*$500.00*	*$500.00*
Torc SafeStop ES-220 Wireless E-Stop System	*1*	*$2,000.00*	*$0.00*
AGM Lead Acid Batteries	*2*	*$195.00*	*$195.00*
Wire, Connecters, and miscellaneous components *(new)*	-	*$900.00*	*$900.00*
Sensors & Electrical Subtotal:		***$45,419.00***	***$28,772.00***
Mechanical			
Quicksilver DC Brushless Motors	*2*	*$2,450.00*	*$2,450.00*
Aluminum Frame	-	*$75.00*	*$75.00*
Trailing Arm Suspension *(new)*	-	*$600.00*	*$600.00*
Low Rolling Resistance Composite Nylon Wheels	*2*	*$0.00*	*$0.00*
Caster Wheel	*1*	*$25.00*	*$25.00*
Pelican Case	*1*	*$112.00*	*$112.00*
Reagle Lift	-	*$50.00*	*$50.00*
Mechanical Subtotal:		***$3,312.00***	***$3,312.00***
	Total:	**$48,731.00**	**$32,084.00**

2.3 Team Organization

As Table 2 shows, over 2000 man hours were spent preparing Reagle for the IGVC competition.

Table 2: 2011-2012 IGVC Team members

		Areas of Concentration					
Team Member	**Academic Major**	**Mechanical**	**Software**	**Electrical**	**Document**	**CAD**	**Hours**
William Meng (Lead)	Mechanical Eng.	☑	☑	☑	☑	☐	860
Jamal Burch	Mechanical Eng.	☑	☑	☐	☑	☐	350
Megan Scheppa	Mechanical Eng.	☐	☑	☐	☑	☐	170
Randy Breingan	Software Eng.	☑	☑	☑	☑	☐	50
Matthew Standifer	Mechanical Eng.	☑	☐	☑	☐	☑	100
Gregg Leonard	Mechanical Eng.	☑	☐	☑	☑	☑	170
Alecia Hurst	Eng. Physics	☐	☑	☐	☐	☐	100
Duncan Miller	Computer Eng.	☐	☑	☐	☐	☐	60
Joseph Pavicic	Aerospace Eng.	☑	☐	☐	☐	☐	60
Krishna Ajmeri	Aerospace Eng.	☑	☐	☐	☐	☐	30
Michael Mikloucich	Mechanical Eng.	☐	☐	☐	☐	☑	50
Total							2000

3 MECHANICAL

3.1 Vehicle Chassis

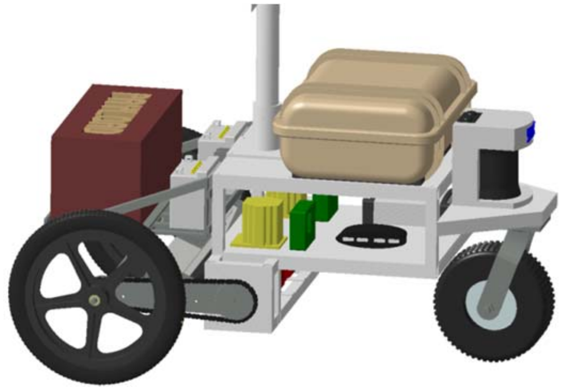


Figure 4: CAD model of Reagle

Reagle's chassis (Fig. 4) is made of 1/8 inch square aluminum tubing, which is welded into a box frame. The chassis houses the majority of Reagle's electronics and sensors. The dimensions of the chassis are approximately 44 inches long, 33 inches wide, and 17 inches tall (exluding mast) with a ground clearance of 4 inches. Attached to the chassis is a 5 foot mast for holding the GPS antenna, camera, compass, and E-stop button. Placing these sensors on the mast improves performance. Attached to the rear of the chassis is the rear rack for carrying the 20 lb. load. This not only keeps the payload from making contact with the electronics, but it also increases traction to the vehicle by adding more weight on the drive wheels. Lastly, mounted on top of the chassis is the electronics box, which houses the power board, wireless router, and emergency stop receiver.

3.2 Drivetrain

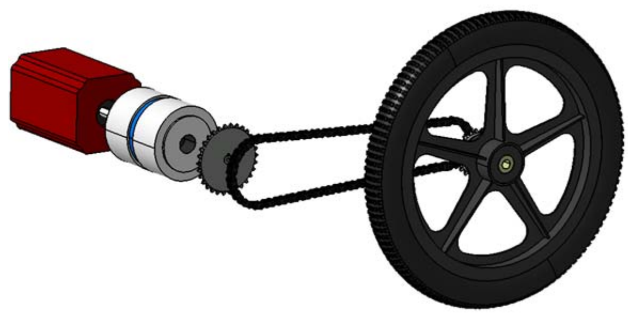


Figure 5: Reagle's drivetrain

Reagle's drivetrain (Fig. 5) consists of two Quicksilver SilverMax 34HC-1 brushless motors. Attached to these motors are NEMA 34 single-stage planetary gear heads. These gear heads transfer more torque from the motors directly to the wheels with a gear ratio of 10:1. A #35 ANSI chain is used to transfer power between two sprockets with an equal number of teeth.

3.3 Suspension System

Reagle's suspension system, like its predecessor, is a trailing arm system. It has, however, been improved such that the arm is much shorter, and a bronze bushing has been welded on the chassis. One problem that Reagle's suspension had last year is that the trailing arm was resting directly on the sprocket attached to the gearhead (Fig. 6). A considerable amount of stress was placed on the gearhead, which caused the gearhead shaft to shear on multiple occasions, and friction increased the required torque from the motors. To resolve this problem the sprocket now rests on a bronze bushing mounted directly on the chassis, greatly reducing the stress to the gearhead. In addition, Reagle's maneuverability is increased due to the shorter moment arm from drive shaft to castor wheel, as well as the increased rear weight distribution.

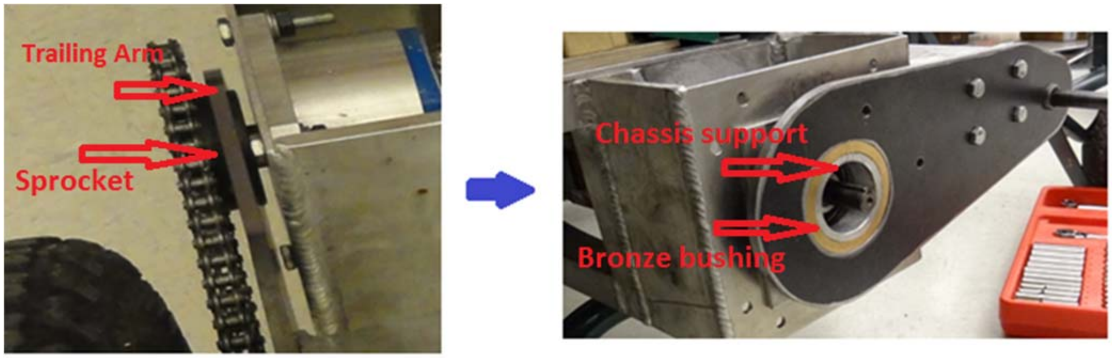


Figure 6: Trailing arm suspension modification

3.4 Predicted Performance

Reagle's Quicksilver motors have a maximum no-load speed of 2500 RPM at 24 volts. Combined with the 10:1 gear ratio and 16 inch diameter wheels, this equates to a theoretical maximum speed of 11.9 mph. Reagle is capable of reaching 8 mph in actual tests.

Reagle weighs in at 160 lb. without the payload and the motors have a stall torque of 680 oz-in. Combined with the gear ratio and wheel size mentioned above, Reagle can theoretically climb slopes of up to 19° (35 gradient). In actual testing, Reagle was able to climb slope of up to 13° (23 gradient).

4 ELECTRICAL SYSTEM

4.1 Power System and Battery Life

Reagle is powered by two 12V MagnaPower ETX16L AGM batteries connected in series, which provides a nominal 24V to the system. These lead acid batteries provide an economic and reliable power source for all of Reagle's components. A cover protects the terminals from shorting or getting wet, which is especially important since the batteries are placed on the rear rack and are exposed to the elements.

The two batteries (Fig. 7) have a capacity of 19 Ahr. Assuming a typical load power consumption of 240 watts, the vehicle can be powered for almost 2 hours before needing a recharge. However, Reagle is typically only run for an hour before recharging to protect the health of the batteries.

Safety was a big factor in battery selection, and AGM batteries are sealed and spillproof. Since the batteries are located outside of the chassis, custom made terminal covers were made to prevent exposed metal terminals.

Figure 7: Lead acid batteries

4.2 Power distribution

The central hub of Reagle's power system is a custom developed power board. The board, E-stop receiver, remote control board, and voltage monitoring system are safely stored within a weather resistant

1520 Pelican case (Fig. 8). Unregulated 24V power flows from the batteries to an in-house designed power board, which can provide regulated 24V, 12V, 5V, and 3.3V to the sensors.

The regulated 24 volts is distributed to the Sick Laser Range Finder (LRF) and to an APlus B-20 ruggedized computer. The regulated 12 volts is sent to the compass, GPS, and LEDs. 5 and 3.3 volts are not currently used but are available for testing new sensors and future expansion. Each of these connectors has an individual fuse to avoid damage from a power surge or short circuit. Figure 9 shows how power is distributed in the system.

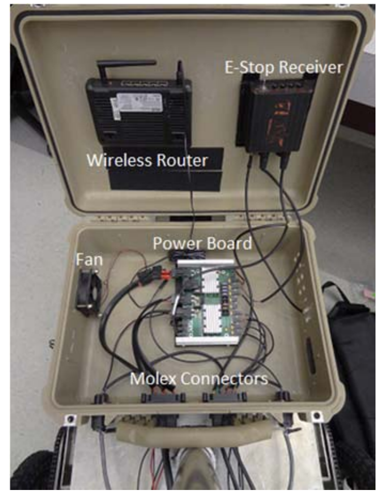


Figure 8: Electronics box

4.3 Power Consumption

Reagle was designed with efficient use of power in mind. Table 3 shows the power requirements of each component in the electrical system. Although maximum consumption is quite high owing to the two motors, average consumption is estimated to be less than 300W. Average consumption is difficult to quantify precisely in large part because they are affected mostly by how much power the motors draw.

Table 3: Max power consumption

Component	Voltage (V)	Current (A)	Power (W)
Motors/Encoders (2x)	24	20.8	500
A-Plus Computer	24	7	168
Laser Range Finder	24	1.8	43.2
DGPS	12	1.25	15
E-Stop Receiver	12	0.75	9
Digital Compass	12	0.003	0.036
Total Maximum Consumption			735.2

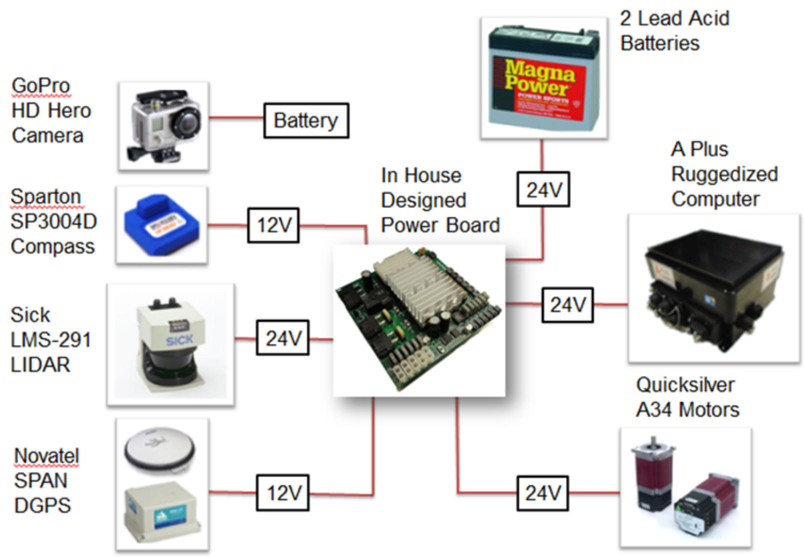


Figure 9: Power distribution flow chart

4.4 Improvements

Last year, Reagle's connectors exited the electronics box from the right hand side as shown in Fig. 10, and this caused problems when the vehicle would collide with obstacles on the right side. The connectors would break and they were not easy to repair or replace. In addition, Reagle experienced many electrical problems that resulted from faulty wiring, so the entire vehicle was rewired. The connectors were replaced with Molex automotive connectors (Fig. 8) and moved to the rear of the electronics box. The connectors now have the convenience of easily removable pins and quick release locks.

Figure 10: Old connector system

4.5 Emergency Stop System and Safely Strobe Light

Reagle incorporates the SafeStop emergency stop system from TORC Technologies shown in Fig. 11. The SafeStop transmitter uses spread spectrum frequency hopping for decreased interference and reliable transmission of up to 6 miles line-of-sight. The transmitter's battery lasts 30 hours on a single charge. As implemented, the SafeStop system provides both a pause mode, which rapidly brings the vehicle to a controlled stop without cutting power, and a "hard" emergency stop that opens a relay, disengaging all electrical power. A separate radio controlled transmitter is used to drive the vehicle in non-autonomous mode. Reagle is also equipped with a strobe light that indicates to bystanders when Reagle is under autonomous control.

Figure 11: E-stop transmitter and receiver

4.6 Sensor System and Integration

Reagle uses four commercial-off-the-shelf (COTS) sensors as shown in Fig. 12 below. The central point of integration is an APlus Mobile B-20 Rugged PC with Core 2 Duo 2.8 Ghz processors, 8 GB RAM, and 40 GB solid state hard drive. The LabVIEW programming environment installed on the APlus is the central point of software integration. LabVIEW is a critical tool used to receive and organize data from the sensors and run all software algorithms. The APlus is accessed by laptop via an onboard wireless connection.

LRF — Sick's LMS 291 laser range finder scans for obstacles in a 180° planar sweep in 1° increments at 20 Hz. The maximum sensing rage is 80 m, but Reagle limits detection to obstacles within 15 m. Resolution is 1 cm, and accuracy is ±3.5cm. Time-of-flight technology is used to calculate the distance to an object from the vehicle. This sensor scans in front of the vehicle and is used for obstacle detection and avoidance algorithms. The LIDAR collects angle and distance information of obstacles over the entire 180° plane and transmits this data to the APlus via RS-232 and a serial-to-USB converter.

DGPS — Novatel's SPAN Differential GPS, used in tandem with a Novatel GPS 702 GGL antenna, combines global positioning satellites with the OmniSTAR HP correctional service. Uncorrected accuracy is usually 1-2m CEP. Correction with OmniSTAR HP decreases the uncertainty to sub-decimeter range. The SPAN system integrates an IMU with a Kalman filter, so continuous inertial solutions can be output at up to 100 Hz. GPS only measurements can be requested at up to 20 Hz. Reagle accesses the inertial solution at 20 Hz. GPS data is transmitted to the APlus via RS-232 and a serial-to-USB converter.

Digital Compass — The Sparton SP3004D digital compass is a six-axis accelerometer/magnetometer that can provide roll, pitch, and yaw (heading) information with 1° RMS accuracy at 0.1° resolution. Reagle accesses the orientation data at 20 Hz via RS-232 and a serial-to-USB converter.

Digital Camera — The GoPro HD Hero is an outdoor sport, consumer grade 5 megapixel digital camera with a very wide 170° field of view lens. 720x480 standard definition video is streamed to the computer with a digitizer and captured at 20Hz. The GoPro camera runs off its own battery power with a typical use time of one hour continuous streaming. Data is sent to the computer through a USB cable. This improves upon previous years' webcam and board cameras, which had smaller fields of view and worse performance in bright outdoor conditions.

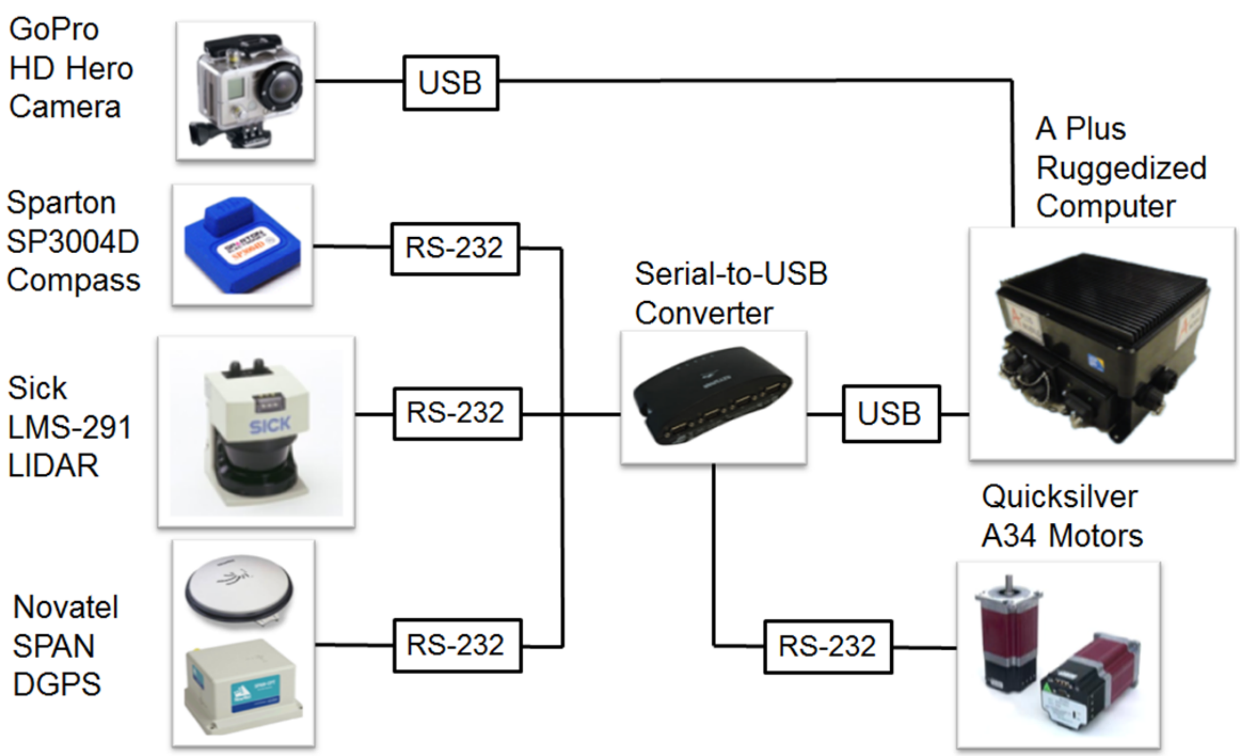


Figure 12: Sensor integration flow chart

5 SOFTWARE SYSTEM

5.1 Structure

Reagle's software system was developed using National Instruments LabVIEW. LabVIEW was chosen because it provides an intuitive Graphical User Interface (GUI) which allows the user to modify software before the code is run. The GUI is helpful in verifying that all of Reagle's sensors and components are fully operational before the autonomous program is run.

The code is broken down into four major sequential steps, with each later process able to make use of and override the previous decision. The steps are waypoint navigation, line following, path planning, and obstacle avoidance (Fig. 13). The path planning step has three possible states depending on which scenario Reagle is currently facing. For example, the flag navigation algorithm is active only after the second to last waypoint is hit.

Figure 13: Software flow chart

5.2 Waypoint Navigation

Waypoint navigation is the first section of the code. Reagle's current position and heading are obtained from the GPS and compass, respectively, and with this information the angular error and the distance to the target waypoint can be calculated. Without the presence of any obstacles, Reagle will simply drive straight to the waypoint. This is depicted in Fig. 14.

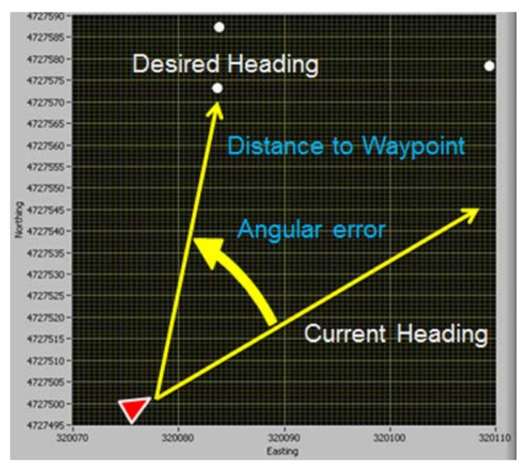


Figure 14: Waypoint navigation

5.3 Line Following

The line following flow diagram, shown in Fig. 15, illustrates the primary steps in the line extraction algorithm. First, box covers are placed at the top and bottom of the image to block out the horizon and vehicle, respectively, since both can have very bright pixels that are not lines. Next the image is down sampled from 720 x 480 to 160 x 120 to blur some noise and reduce processing time. A mixed plane threshold is performed to obtain a grayscale image. The image is also split into a left and right half, since there are potentially two dominant lines in the image.

To pick out the white pixels, a brightest pixel algorithm is used, which scans both horizontal and vertical lines for the pixel(s) of highest value. A Hough transform uses a voting system to determine the slope and distance to the dominant line of each half-image. It is possible that no line is detected in the image if no candidate receives a minimum number of "votes" in order to be considered a line.

The last step is to recombine the half-images and use a decision tree to select the heading given the possible combinations of lines in half-images. For example, if both images detect a line, the heading should be between them. If only one image contains a line, then the heading should be a few feet left or right of this line as appropriate to stay within the course, etc.

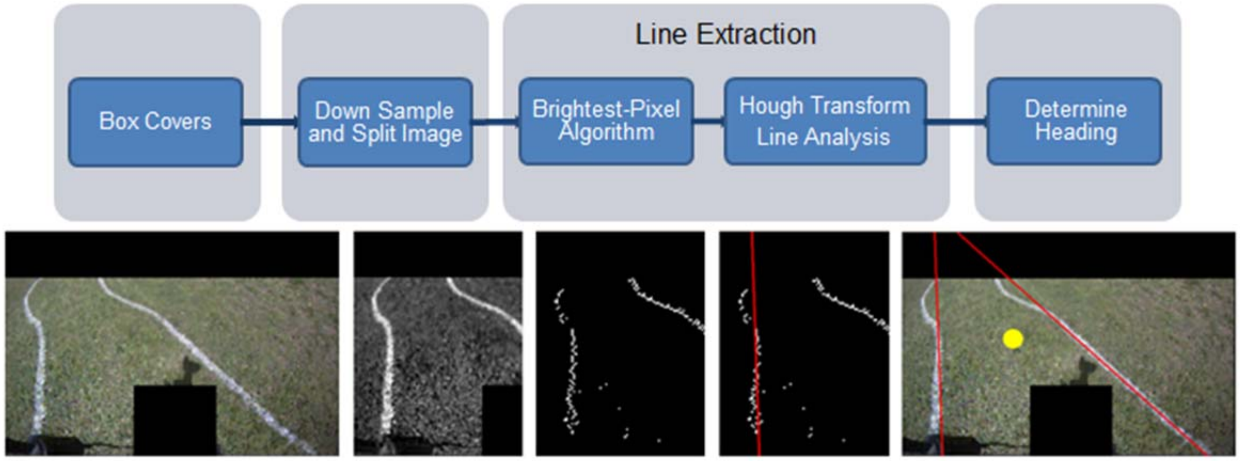


Figure 15: Line detection algorithm

5.4 Flag Detection

This year, there are blue and red flags that are arranged in a more complex arrangement than previous years. The flag detection algorithm uses three simple steps (Fig. 16). First, it retains the same box covers as the line detection algorithm to block out parts of the image that are near the horizon or vehicle. Then it performs a mixed-plane threshold based on hue (color), RGB ratios, and HSL values to determine pixels that qualify as either blue or red. Finally, a particle filter is used to eliminate blobs that are too small or too large to possibly be flags. The results are overlain on the GUI so that the user can immediately see what has been detected as a flag and make adjustments as needed.

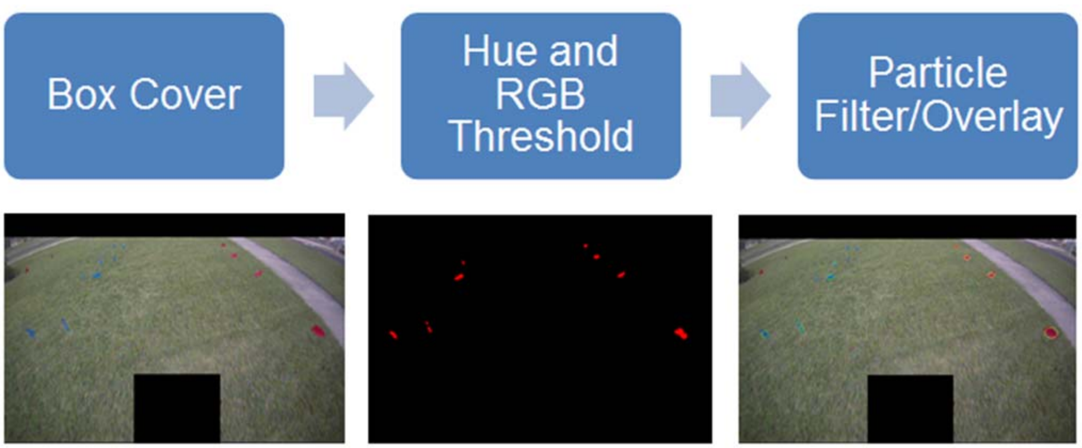


Figure 16: Flag detection

5.5 Potential Fields Path Planning

For obstacles that are more than 2 meters away, Reagle has a new path planning algorithm that is based on the concept of potential fields. The potential field method is essentially an equation of attractive and repulsive forces:

$$F_{att} = k_{att} * d_{wypt}$$

$$F_{rep} = \frac{k_{rep}}{d_{obs}^2}$$

$$F_{tot} = F_{att} + F_{rep}$$

The attractive force pulls the vehicle towards the waypoint, while the repulsive forces push the vehicle away from obstacles (Fig. 17). The sum of these forces determines the desired direction of the vehicle. These virtual forces are functions of the distance to the waypoint and distance to the obstacle.

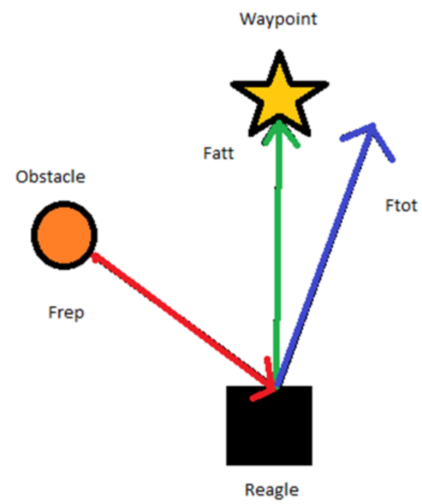


Figure 17: Potential fields path planning

The major problem with potential fields is the phenomenon known as local minimum. Local minima occur in situations where the vehicle enters symmetrical traps such as dead ends. At a local minimum, the repulsive forces act so strongly around the vehicle that they are essentially equal to the attractive force. This causes the vehicle to come to stop and be unable to reach the waypoint. In order to avoid local minima, the gains for the attractive and repulsive forces have been tuned such that it is less likely to occur, and a wall following algorithm has been implemented which is explained further in the dead end section.

5.6 Gap Selection Path Planning

Although Reagle does not implement any sort of mapping over time, it does make use of a long range optimal heading algorithm. At any given instant, Reagle can see 180° of objects at up to 80 meters away; however, the obstacle avoidance algorithm only makes use of data points that are within 2 meters of the vehicle. This results in somewhat clumsy paths that can be characterized as simply straight lines towards the next waypoint until an object is within 2 meters, at which point the vehicle will make a sudden left or right turn.

The new path planning algorithm eliminates this sub-optimal behavior by making use of data within a range of 15 meters. It analyzes the obstacle data and segments objects so that any gap that is large enough for the vehicle to pass through, about 1.5 meters, is marked as either a left-handed or right-handed opening. In Fig. 18 below, the small green circles represent left-handed openings and the red circles mark the right-sided ones. The green arrow shows the heading that the algorithm has determined leads to the optimal opening. With this algorithm, Reagle can drive straight to the optimal opening instead of simply driving straight until it is in close proximity to an obstacle.

Given the limitations of the LRF, namely that it cannot see through objects, this technique provides optimal behavior going towards unknown parts of the course, because even a mapping solution cannot map unknown parts of the course given the same sensors.

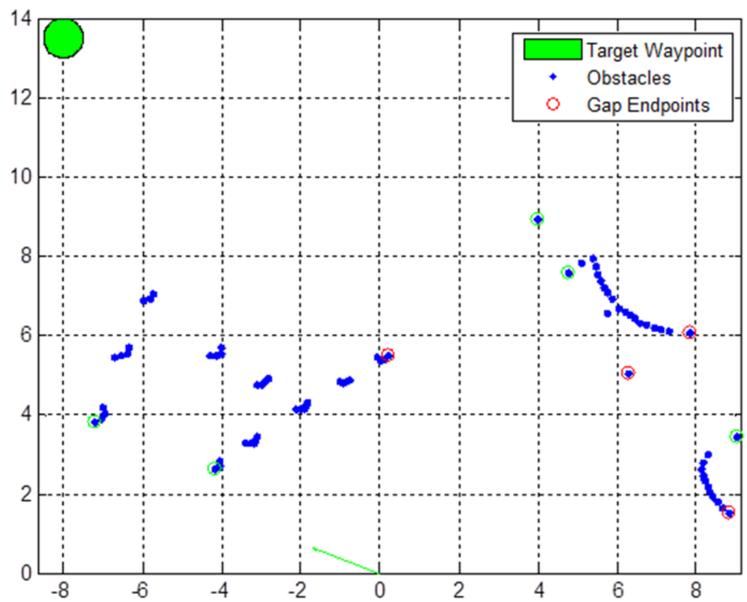


Figure 18: Gap selection path planning

5.6 Obstacle Avoidance

Reagle's obstacle avoidance algorithm operates when the vehicle is within 2 meters of an obstacle. The LRF is the sensor that provides information which allows the obstacle avoidance algorithm to be used. The LRF's 180° field of view is broken into five zones: center, middle left/right and far left/right. Fig. 19 below shows the vehicle with the zones defined. The segmentation of these zones can be modified by the user but are currently set at: 0° (due right), 30°, 65°, 115°, 150°, and 180° (due left). A zone is considered occupied when an obstacle is within 2 meters. When a zone is occupied Reagle turns in the opposite direction.

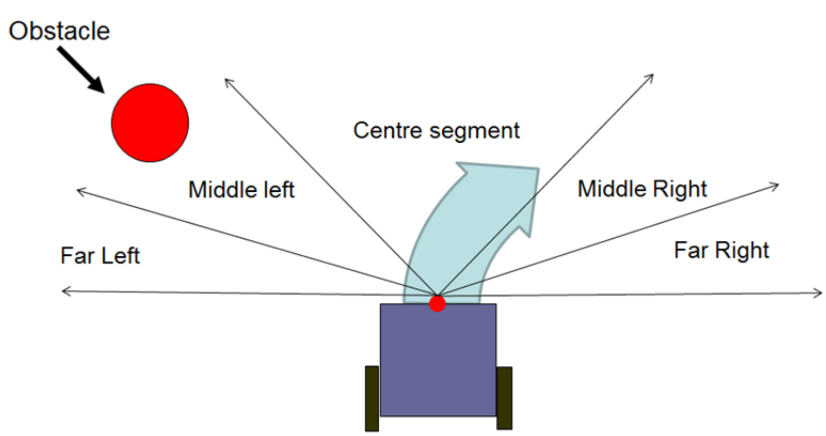


Figure 19: Obstacle avoidance zones

While each zone is labeled as occupied or unoccupied, the algorithm continuously uses a decision tree to decide the path to avoid obstacles. The main check on the decision tree is to check if the center cone is occupied. If that cone is occupied, it goes on to check if the previous command was left or right. Next, the middle left or right, respectively, is checked to see if it is occupied. This decision tree continues on for all possible combinations of cones and objects.

5.7 Complex Obstacles

5.7a Switchbacks

A switchback occurs when the vehicle has to successfully navigate through a zigzag like obstacle course. Reagle is programmed to handle switchbacks using the waypoint navigation and the five zone obstacle avoidance. The waypoint navigation knows where the waypoint is located and uses the angular error to calculate the desired heading. Obstacles are avoided by using the five zone obstacle avoidance; Reagle will recognize the minimum gap of five feet and be able to make it through without hitting any of the obstacles. The desired path Reagle would take for a switchback situation is depicted in Fig. 20.

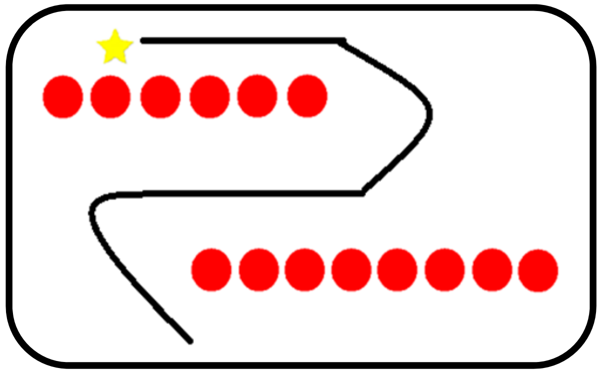


Figure 20: Switchback strategy

5.7b Dead Ends

A dead end is a complex situation that Reagle is not able to handle only using the waypoint navigation and the five zone obstacle avoidance. With only these, Reagle would just end up circling in the dead end continuously. To correct this, a dead end algorithm had to be implemented. The dead end algorithm is broken down into three sections. The sections are: recognizing the dead end, the action to take in order to get out of the dead end, and turning off the algorithm.

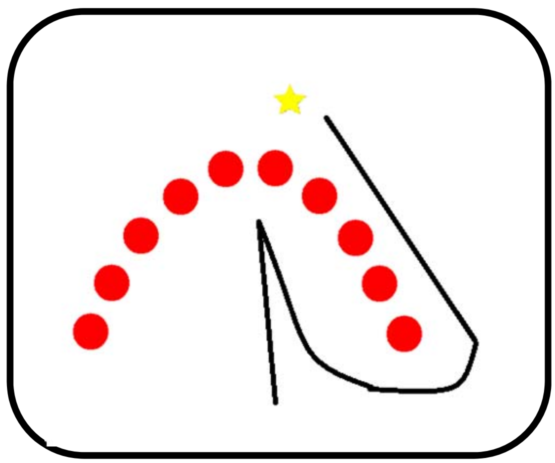


Figure 21: Dead end strategy

Reagle recognizes the dead end by constantly checking to see if there is an obstacle in the three main zones for more than fifty percent of the time. This, in conjunction with any turn greater than 120°, will activate the dead end algorithm. The plan for getting out of the dead end is to use wall following. Reagle will follow the wall in the opposite direction of the original 120 degree turn. The code will turn off when Reagle moves a certain distance away. If Reagle ends up in the dead end again, the code will again turn on, but this time Reagle will follow the wall in the opposite direction. Fig. 21 shows how Reagle would get out of a dead end situation.

5.8 Matlab Simulator and Data Replayer

This year, the software also has a new data logging system which outputs all sensor and algorithm information into a text file that can be imported into Matlab and replayed. This helps immensely with identifying problems because incorrect values from the algorithms cannot be immediately noticed by inspection of vehicle performance in a particular test.

The output of the program is shown in Fig. 22. The black rectangle represents the vehicle's footprint, while the blue represents obstacles, and the green circle is the target waypoint. The green semi-circle extending from the vehicle is the obstacle avoidance range, and any obstacles within that range will be reacted to. The red dots show the vehicle's GPS trail. On the left hand side are numerical values that can be customized to whatever the user wishes to see, including elapsed time, wheel speeds, latency, etc.

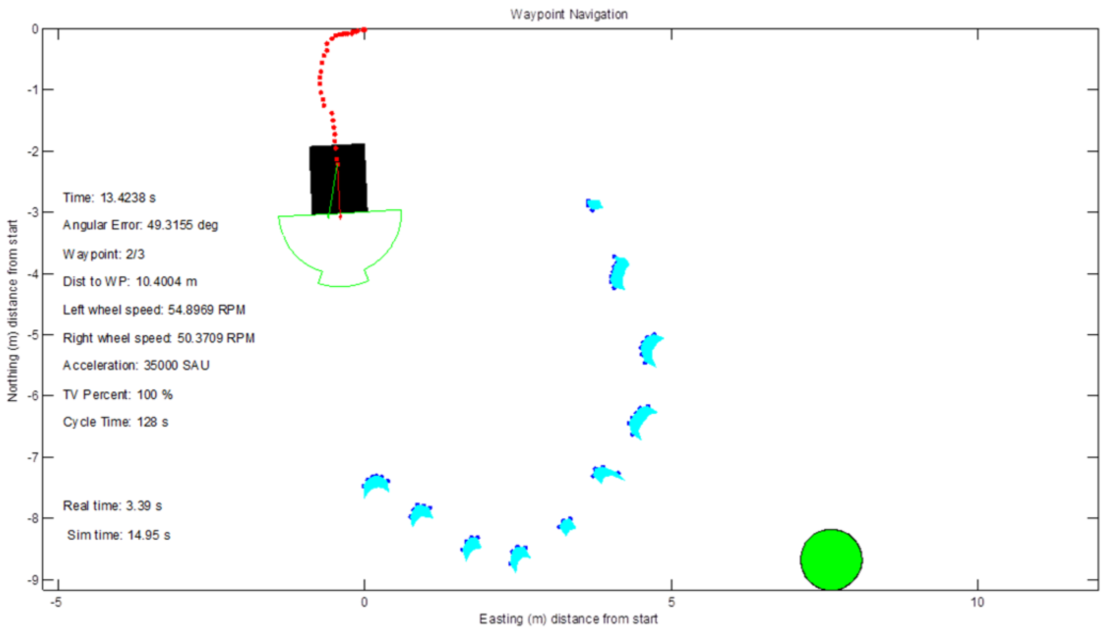


Figure 22: Matlab simulator

6 COMMUNICATIONS

6.1 JAUS Protocol

The Joint Architecture for Unmanned Systems (JAUS) is an SAE standardized communication protocol that has been implemented on Reagle. This software requires a sequence structure, which creates a timeline of events. The first event opens the port and UDP connection to the controlling unit. Reagle then broadcasts a Query Identification every 5 seconds. Once the control unit responds, the next sequence is started.

The second event parses, sends and receives JAUS messages. Reagle receives messages faster than it can process the messages. Even so, all of the messages are processed in the order of reception and placed into an event queue. Once the message is removed from the queue, the first action required is to determine the validity of the messages by checking the origination identity, as well as the sequence number to ensure messages being received only once. Once a message is determined to be valid, the message identity is determined and the remaining message data is handled appropriately. Responses are placed into another event queue, sequenced into a header and trailer, and sent to the control unit.

6.2 Latency (Reaction Times)

Reagle's software code is able to run at about 9 Hz on an Intel i5 2.30 Ghz dual core processor and 8 GB RAM on Windows 7 (x64). The vision algorithms take about two-thirds of this processing time. Reagle can access sensor data at 20 Hz or faster, so the limiting factor is the speed of Reagle's main algorithm process.

Table 4: Latency

Latency		
Process		Time (ms)
Grab Camera Image		21
Vision	Line detection	40
	Flag detection	25
Path Planning		20
Obstacle Avoidance		9
Total		115

7 CONCLUSION

Reagle V is based on a reliable legacy vehicle platform, but it incorporates substantial improvements in hardware and software that will allow it to meet all challenges of the 2012 Intelligent Ground Vehicle Competition. With the addition of new innovative features and based on extensive testing, we believe Reagle V will provide an adaptable and reliable platform for this and future competitions.

8 ACKNOWLEDGEMENTS

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