Embry-Riddle Aeronautical University

Derivative of Last Lightweight Entity (DOLLE)

Team Members: *Zachary Bryant, John Garcia, Christopher Hockley, Heather Lloyd, Diego Lodato, John Mecadon, Nick Middlebrooks, Kody Miller, Allen Perron, Zachary Saidman, Marco Schoener, Yates Simpson, Nigel Smith, Parker Tyson, Tim Zuecher*

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Introduction

Derivative of Last Lightweight Entity, also known as DOLLE, is an autonomous vehicle used for intelligent navigation. The latest vehicle designed at Embry-Riddle, DOLLE was built with the goal of making the most lightweight, functional robot possible with a low cost. The name pays homage to Embry-riddle's vehicle from years past, MOLLE. Although similar in name, DOLLE is in no means a clone of MOLLE. DOLLE's design incorporates novel mechanical, electrical, and software system features that emphasize simplicity, safety, modularity, and ease of operation. This advanced IGVC vehicle includes desirable features not seen in many other competitors including portability, ruggedness, and remarkable agility during operation. This report outlines the development of these systems and the methods used for system integration.

Team Composition

The development of DOLLE required a multidisciplinary engineering team capable of working on several different aspects of the vehicle. The team put more than 3310 hours into the design, manufacturing, and implementation of DOLLE and its software. The DOLLE team consists of the following 7 team members listed in alphabetical order in Table 1. The symbol "*" denotes each team member's main focus for the year.

Table 1: Team Composition

Areas of Concentration						
Team Member	**Major**	**Mech.**	**Soft.**	**Elect.**	**Doc.**	**Hrs**
Nick Middlebrooks	Mech. Eng./Grad Student		X*	X	X	820
Yates Simpson	Mech. Eng./Grad Student		X*		X	710
Zachary Bryant	Mech. Eng./Sophomore	X*	X			
Christopher Hockley	Ph.D. Candidate/Mentor	X*				200
Kody Miller	Mech. Eng./Sophomore	X*	X			
Allen Perron	Mech. Eng./Sophomore	X*				
Zachary Saidman	Mech. Eng./Junior	X*				
Marco Schoener	Mech. Eng./Grad Student		X*			300
Parker Tyson	Mech. Eng./Sophomore	X*	X			
Tim Zuecher	Ph.D. Candidate/Mentor		X*			200
John Garcia	Mech. Eng./Graduated	X*	X			480
Heather Lloyd	Mech. Eng./Graduated		X*	X		510
Diego Lodato	Mech. Eng./Graduated			X	X*	420
John Mecadon	Mech. Eng./Graduated	X*			X	460
Nigel Smith	Mech. Eng./Graduated	X*				440

Design Process

The development of DOLLE uses a seven-step design process as seen in Figure 1 that began with determining the problem presented by the competition. For the IGVC competition, the problem is to develop a robot that can successfully navigate through an obstacle course and a series of waypoints, while reacting from visual cues from painted lanes and colored flags. The customers are the IGVC competition judges, faculty, and future team members. With those customers in mind, new specifications were developed to meet the new competition standards.

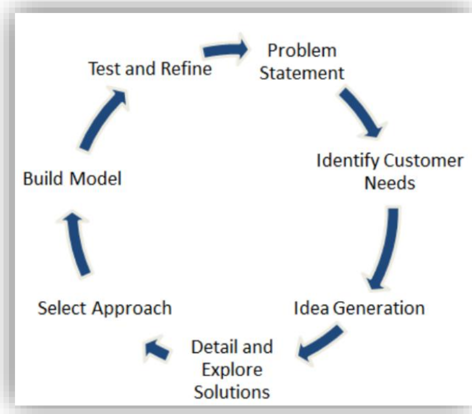

Figure 1 Design Process Approach

Innovations

Small, Lightweight, easily manufactured

Teams competing in IGVC have a long running trend of designing large, complex vehicles. The DOLLE platform offers a compact, tightly integrated design capable of performing tasks on par with the previous ERAU large and bulky systems. Notable features include:

- Simulator for software testing off-board
- Modular system packages that can be attached directly to the frame.
- Backwards-compatibility from older sensors
- The sensor mast is removable to simply transport alongside the vehicle.
- Kickstand for safety and bench testing
- Onboard voltage monitor
- Quick disassembly for compact storage and easier travel/carrying

Modular software

The DOLLE software system is simple in its design and elegant in its implementation. The goal of the design was to produce a highly cohesive software system with low coupling. The implementation of asynchronous message passing aided in making this software system simple and robust. Software was broken down into modules such that each sensor, actuator, and control loop had its own executable file. Using asynchronous messages, these software modules broadcast messages to other modules without being directly coupled. This is a comparable system to how ROS operates, but in the LabVIEW environment that is used by 3 of the 6 ERAU AUVSI competition teams, which allows code to be quickly and easily shared between teams.

Vehicle Cost

Due to sponsorships and the reusing of parts from previous competition models, DOLLE was able to be constructed at minimal cost to the team. Table 2 shows a list of components that were used in DOLLE, with the cost to the team and estimated market value. The final cost of the DOLLE system is very low compared to systems used by other competitors, which coupled with the hot-swappable sensor system allows for a low-cost, versatile system that can be reused in different environments.

Table 2: Vehicle Cost

Item	Unit Cost ($)	Qty	Raw Cost ($)	Team Cost ($)
Laptop	$750	1	$750	$0
Wiring and misc.	$180	1	$180	$180
Power Board	$89	1	$89	$89
ION Action Camera	$40	1	$40	$40
Digital Compass (IMU)	$1,350	1	$1,350	$0
LiPo Batteries (6s)	$45	3	$135	$0
Motors	$2,200	2	$4,400	$0
Wheels	$20	2	$40	$0
GPS	$3,000	1	$3,000	$0
LiDAR	$8,000	1	$8,000	$0
Aluminum Frame	$22	1	$22	$22
Transmitter	$255	1	$255	$0
			$18,261	$331

Mechanical Design

Frame Design

The chassis of DOLLE is a simple A-frame, designed with safety and portability in mind, this platform has been a proven design based upon ERAU's past entries. The frame is completely constructed out of aluminum in order to minimize overall system weight and maintain rigidity. Two round PVC handles can be screwed into the front and back of the frame. There are two purposes for the handles, the first is the handles provide a safety bumper to prevent any damage to the system or people. Second, the handles provide carrying points for DOLLE when it needs to be transported from the lab to the testing fields. The left side of Figure 2 shows DOLLE's frame and handles.

All non-ruggedized electronics are housed inside a pelican case, which makes the vehicle virtually waterproof (rated to IP65). The payload and computing system are attached to the top of the frame as shown on the right side of Figure 2. The connectors running into the box are also IP65 rated to prevent water from entering the box and damaging the computer components inside.

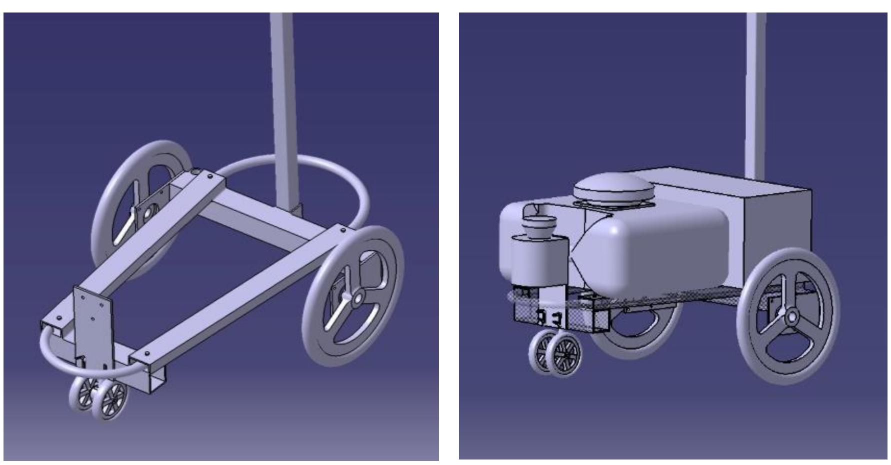

Figure 2: DOLLE base system frame and fully loaded configuration

Sensor Pole

The sensor pole, seen in Figure 3, is made of 1" square carbon fiber tubing mounted upright from the base of the frame. Carbon fiber was chosen for its rigidity, durability, and lightweight properties. The sensor pole holds the Ion Action Cam, Hemisphere GPS, safety lights, and the emergency stop button. The wires for the components are fastened to the sensor pole to allow for quick-swapping of cameras or light options. The sensor pole is a highly modular structure, as all the sensor attachments are able to be quickly removed without removing the pole from the base of DOLLE.

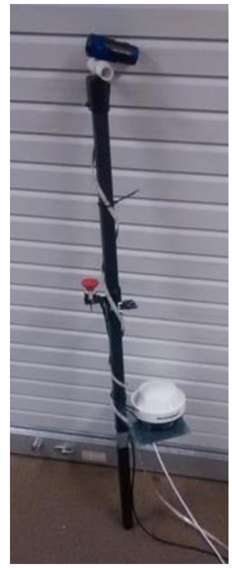

Figure 3: Sensor pole

The Ion camera can be removed quickly to replace the battery pack with a freshly charged pack to allow for all-day running. The height of the pole is also important because it allows for a high vantage point for the camera for better ground-plane interpolation

The GPS mount is also a quick removal which allows for easy changes in configuration. The base model of the Hemisphere GPS could be switched out for a stronger or weaker GPS system per the requirements of a customer.

The physical E-Stop button is also located on the pole with an adjustable height option to allow for ease of use for all operators.

Motors & Gearbox

The motor assembly consists of a pair of 24 Volt Quicksilver motors and OEM NEMA 23 Series gearheads connected to two 12 ½" diameter Skyway tires. The motors are mounted directly to the frame to allow for ease of access. The motors generate the 20inlb of torque needed to reach the maximum 5MPH speed limit while still keeping traction even when going over the ramps.

Quick Service Tool Box

A tool box is affixed to the top of DOLLE's payload. The tool box contents, seen in Figure 4, are listed below and are sufficient to perform most servicing operations on DOLLE when operating on the testing fields, but there is additional space for future tools.

1. 3/4in socket with 3/8in drive wrench
2. 5/16 combination wrench
3. Medium sized Philips screwdriver
4. Electrical tape
5. Wire cutters
6. Extra nuts and bolts 8-32 x3
7. Adjustable wrench
8. 3mm T-handle Allen wrench
9. Flat blade screwdriver
10. Multiple zip-ties

Figure 4: Toolbox contents

Weatherproofing

Because the vehicle must operate in light rain at competition, waterproofing is paramount. All external wires and sensors have been waterproofed, and the main computing system is housed in a weatherproof case which is simply attached to DOLLE's frame. Thanks to this system, not only is DOLLE extremely easy to set up and break down, but it is also IP65 rated.

Power Systems

Custom Power Distribution and Control Circuit

The central hub of DOLLES's power system is a custom developed power board. Unregulated 24V power flows from the batteries to the power board, which can provide regulated 24V, 12V, 5V, and 3.3V to the sensors. The system overview can be seen in Figure 5.

The electrical system is one of the more complex subsystems leading to a high number of potential failure points. For this reason, the team spent substantial time working to design and document the electrical system of DOLLE before implementing it into the hardware. The DOLLE team designed and manufactured a custom power distribution and control circuit board, which acts as the central hub for DOLLE's power system. This minimized the risks that are associated with incorrect internal wiring.

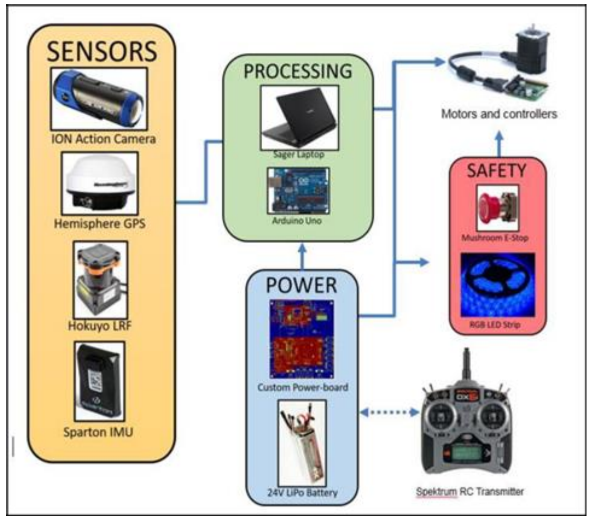

Figure 5: DOLLE system Diagram

The custom printed circuit board provides all necessary operating voltages for each of DOLLE's components. Unregulated 24V power flows from the batteries to the power board, which is then regulated and sent to the sensors. The power board can run the overall system for 1 to 1.5 hours on a 5Ah 6-cell LiPo battery. The overall runtime of the vehicle can be extended with a built-in hot swappable battery system that keeps the system running continuously. Each power connector for each of the components is protected by a fuse in the case of a power failure. The total power distribution of DOLLE

Table 3: Sensor power ratings

Sensor	Power Consumption	Voltage Range	Operating Voltage	Sources
Hemisphere A325 GPS	4.6 W	7 – 36 V	12 V	Power Board
Sparton GEDC-6E IMU	0.32 W	3.3 V	3.3 V	Laptop via USB
Ion Action Cam	1.5 W	3 – 5 V	3.7 V	Battery Pack
Hokuyo UTM-30LX-EW	8 W	10.8 – 13.2 V	12 V	Power Board
Quicksilver Motors	150 W	12 – 48 V	24 V	Power Board
E-Stop	0 W	10 – 40 V	12 V	Power Board
Laptop	6 W	19V	19V	Battery Pack

The power board has an extra connector slot at each voltage rating to allow for new components to be integrated in the future. The board also provides remote control function from an R/C transmitter and both wired and wireless e-Stop capability. This all-in-one board is critical to the compact packaging layout in DOLLE.

Hot-Swap Capability

Thanks to the design of DOLLE's electrical system, it is possible to swap out batteries during testing without having to re-initialize all of the hardware and software. This innovation was implemented in order to reduce the down-time of DOLLE during testing and competition runs.

Electrical & Sensing Systems

Safety Systems

DOLLE incorporates a direct voltage cutoff system built into the power board in case of emergency. This system cuts off power to the motors but keeps the sensors running to avoid a long restart time. E-Stop buttons are located both on the sensor pole and on the RC controller. In addition to the mechanical emergency stop system, an LED strip indicates to bystanders when the system is under autonomous or manual control.

In addition to the hardware E-Stop, the power board also has a software E-stop for the motors as a redundant system. Where the hardware E-stop kills the power to the motors, the software E-stop sends a zero-speed command to the motors, which allows for a quicker restart time after being E-stopped compared to the hardware E-Stop. The RC controller emergency stop has a range of 0.25 miles, and when DOLLE exits that range, it is automatically stopped.

Motor Interface

DOLLE uses an onboard Arduino-based microcontroller that is embedded inside the custom power board to relay commands to the motors. The microcontroller receives motor commands from both the laptop over the RS-232 serial interface and the radio controller, meaning DOLLE can be controlled manually independent of a computer.

Sensor System and Integration

The central point of sensor and communication integration is DOLLE's onboard laptop with a Core i7 2.50 GHz processor, 16 GB RAM, and 500 GB solid state hard drive. The laptop runs a custom LabVIEW 2014 software package for hardware communication and implementation of the autonomy algorithms. The LabVIEW programming environment is a critical tool used to receive and organize data from the sensors and run all software algorithms in parallel. DOLLE uses the following commercial off-the-shelf (COTS) sensors: a Hokuyo UTM-30LV-EW, a Hemisphere A325 GPS, a Sparton GEDC-6E IMU, and an Ion Action Camera.

LiDAR

The Hokuyo UTM-30LX-EW laser range finder scans for obstacles in a 270° planar sweep in .25° increments at 20 Hz. The maximum sensing range is 30 m, but DOLLE limits detection of obstacles within 15 m. Resolution is 1 mm, and accuracy from 0.1-30m is ±50mm. 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 data is transmitted to the laptop via Ethernet using TCP/IP protocols.

GPS

The Hemisphere A235 is a single unit GPS receiver and antenna that can gather GNSS and GLONASS L band signals and updates every at 20 Hz. The uncorrected accuracy is typically between 1 to 2 m. However, the corrected accuracy with OmniStar HP brings the CEP down to around 0.1 m. GPS data is transmitted to the laptop via RS-232 and a serial-to-USB converter.

Digital Compass

The Sparton GEDC-6E Inertial Measurement Unit (IMU) is a 9-DOF system with an accelerometer, gyroscope, and magnetometer, which allows for highly accurate measurements of roll, pitch, and yaw. The accuracy in the heading is a 1° RMS accuracy at 0.1° resolution. The orientation data update at 20Hz and communicates over a RS-232 serial line with a built-in USB converter.

Digital Camera

The Ion Action Camera is an outdoor sport, consumer grade 12-megapixel digital camera with a wide 170° field of view lens. The camera is configured to output 720x480 standard definition video. This video is streamed to the computer with a digitizer and captured at 20Hz. The camera runs off its own battery power with a typical use time of 2.5 hours of continuous streaming.

Software Architecture

Structure

The software was developed in the National Instruments LabVIEW environment. As part of this software DOLLE has an intuitive Graphical User Interface (GUI) to monitor, modify, and tune system functionality in real-time. The GUI helps verify real-time sensor statuses and path planning decisions for the current course. The flow of the code is organized for parallelized decisions that feed into a centralized trajectory planner. The highest priority for DOLLE's trajectory planner can be seen in Figure 6.

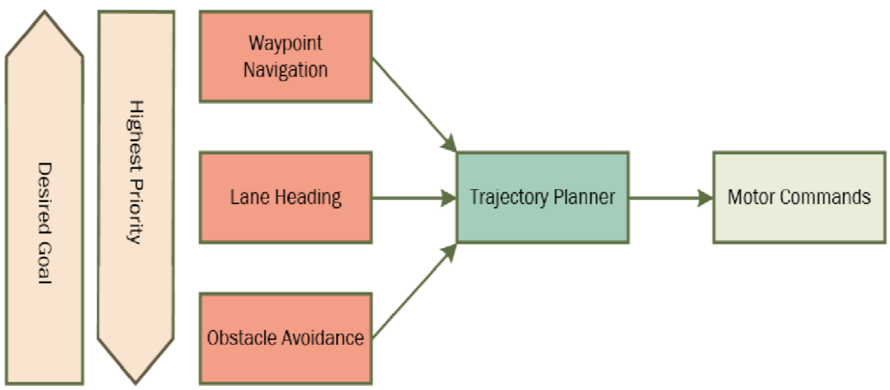

Figure 6: Software priority

Software Overview

The software overview can be seen in Figure 7, which has been rewritten over the past year. DOLLE runs on a publisher/subscriber module system, where the sensor modules read the raw data from the sensors and then send the processed data into a queue. This queue is then read by the Basic Robotic Autonomous Navigation (B.R.A.N.) module where the data is fed into the path-planning algorithms. The output of the path-planning is sent into the motor module, where it is converted and sent to the motors.

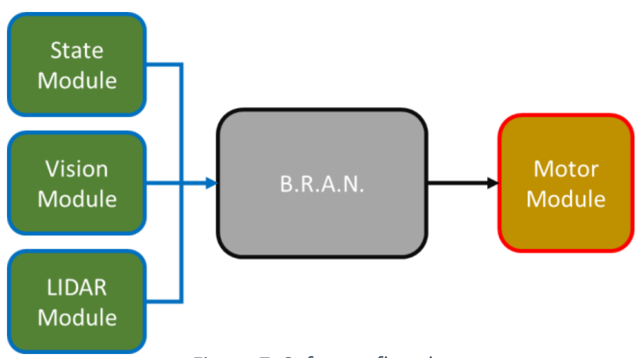

Figure 7: Software flowchart

Modularity

The new software implementation integrates a new software system design which was developed by students within the Robotics Association of Embry-Riddle for the Maritime RobotX competition. This structure, referred to as "Minion Core", allows the software to work as a system of modules, which allows LabVIEW to more efficiently handle parallel-processing tasks while retaining the ability to hot-swap sensors. This structure consists of several individual modules that run independently of each other so the system doesn't go down if one of the modules isn't running. This also allows for better parallelization of the code to more efficiently process the data. This is implemented in the sensor modules by having a driver system to identify what messages are being received to automatically determine how to read the data from that sensor. The Minion Core is the framework though which the publisher/subscriber messages are created and sent through.

Waypoint Navigation

The lowest priority for DOLLE's trajectory planner is to follow the current waypoint location. This means that DOLLE's final destination is the waypoint, but the lane heading and obstacle avoidance determine the actual path on how DOLLE will reach the waypoint goal. The waypoint navigation algorithm calculates the angular difference and error to the waypoint by using the GPS's position data and the IMU's heading data. The navigation data is sent to the trajectory planner as the goal point for all navigation data.

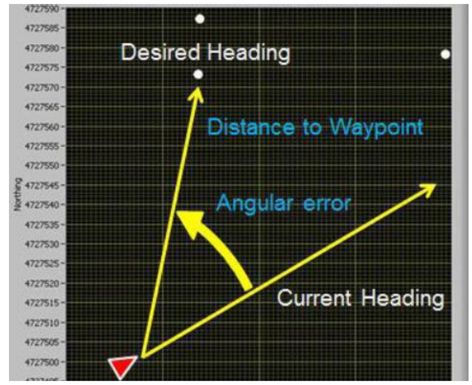

Figure 8: Waypoint angular error

Lane Following

Once the direction to the waypoint is determined, the next section of code implements Lane following. The Lane following flow diagram, shown in Figure 9, illustrates the primary steps in the line extraction algorithm. The algorithm's goal is to first prepare the image feed for image processing, then extract the location of the lanes. To prepare for image processing, irrelevant data such as the sky's horizon and the robot's frame are cropped out from the image. The image is also resampled at 360 X 180 resolution and blurred with a Gaussian filter to reduce processing time and blur out noise respectively from the image.

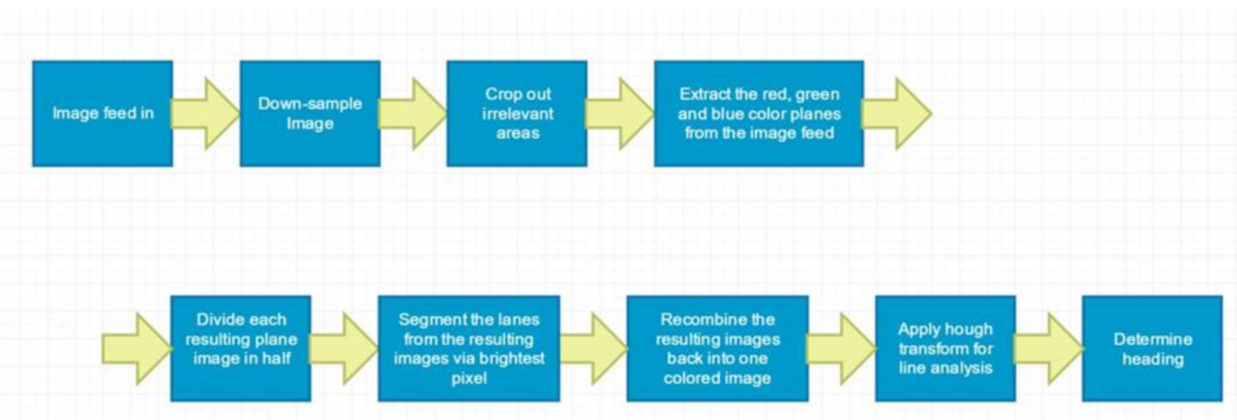

Figure 9: Lane following flowchart

After preprocessing, lane segmentation takes place by extracting the three primary color planes, red, green and blue from the image feed. Each color plane image is divided in half for parallelized image processing, and a brightest pixel algorithm is applied to each divided image. The brightest pixel algorithm isolates the white pixels by scanning both horizontal and vertical axis of the image for the pixel(s) of highest value. The result is the segmented lanes within each color plane. To be robust to various lighting conditions, the results from the three primary color planes are combined into one final colored image as seen in Figure 10.

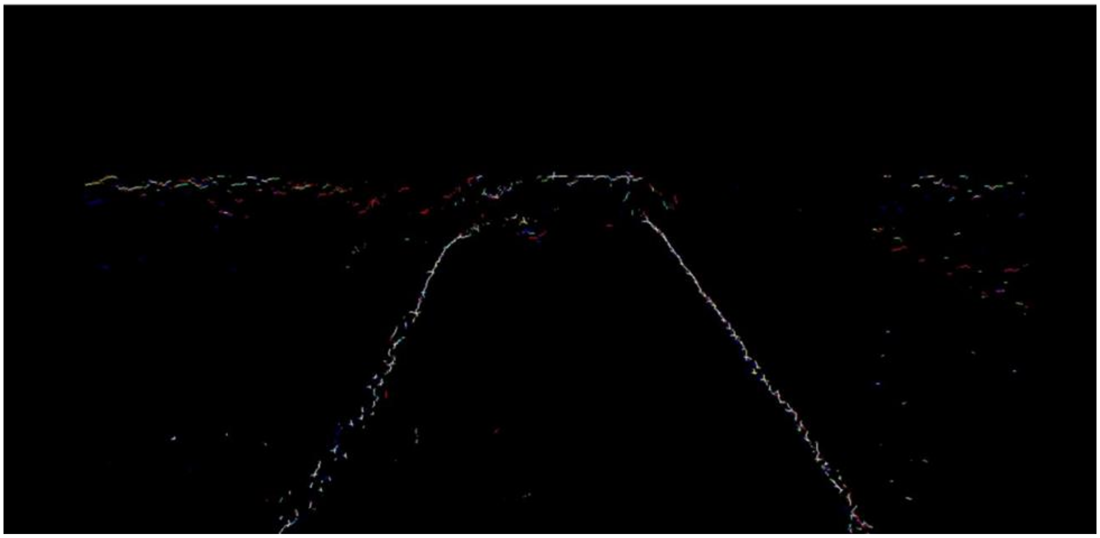

Figure 10: Segment the image

After this, a Hough transform is used to find the best fit lines in each image half. 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. If lines do exist, they are categorized as horizontal or vertical, and compared with each other as parallel or intersecting. The last step is to recombine the half-images and draw an overlay on the location of the lanes as seen in Figure 11.

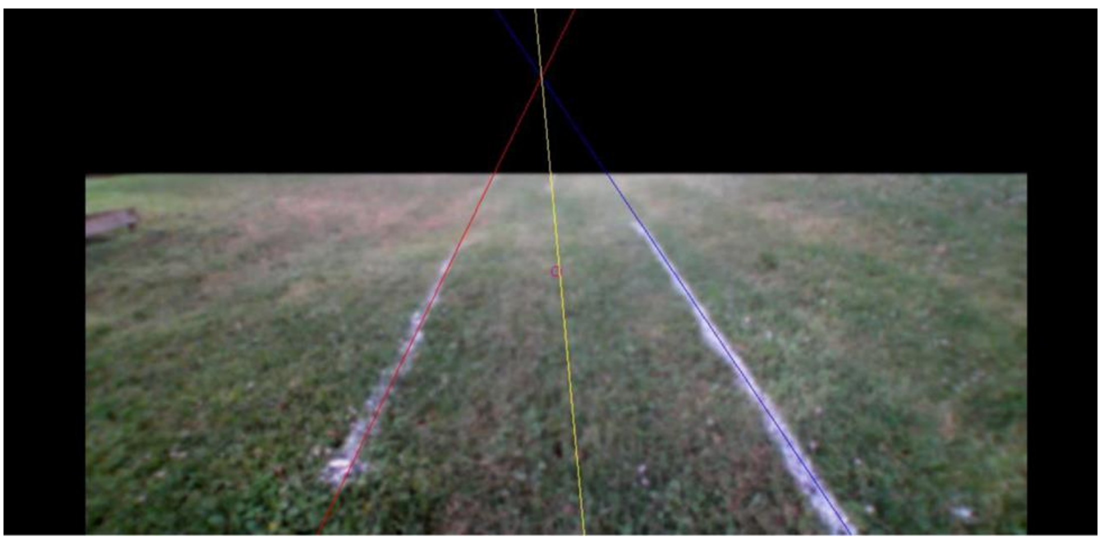

Figure 11: Identified lane

A red line represents a line on the left, a blue line represents a line on the right. A decision tree is then used to select the heading given the possible combinations of lines as seen in Figure 8. A yellow line is then displayed in the image to represent this desired heading. For example, if two lines are detected, the heading should be between them. If only one line is detected, then the heading will be a few feet left or right of this line as appropriate to stay within the course.

Pothole and Ramp Detection

The next stage in the vision processing is to identify the potholes and the ramp in the image. In both cases, the algorithm checks the image for a particular shape of a set area: a circle or a rectangle. If the circle criteria is met, the algorithm will identify this as a pothole; whereas, if a rectangle criteria is met, the algorithm will identify this as a ramp. When the ramp is detected, its entire visual appearance shines as bright as the surrounding lines due to its high spectral reflection. The ramp problem is combatted by generating a blank strip down the center and uses the edges of the ramp as a pseudo-line, especially since the actual lines are within a few inches of its edge. The pothole information is then passed to the Obstacle Avoidance algorithm to ensure the pothole is treated as an obstacle.

Path Planning

The trajectory planner is responsible for generating an appropriate heading for DOLLE to follow based on all the information fed to it from the active algorithms. It is made up of two parts: the desired heading and the desired goal. The heading is selected based on available algorithm data from the software subsystem hierarchy seen in Figure 12.

The desired path goal uses a reverse priority order: waypoint navigation, lane heading, and then obstacle avoidance from the Advanced VFH. The goal heading is the next desired waypoint. The desired heading is the desired outcome from the algorithm.

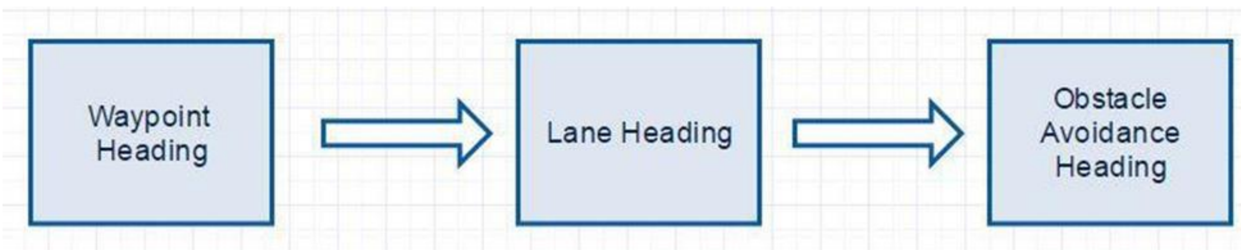

Figure 12: Path planning flowchart

The waypoint navigation subsystem is the first step in finding the goal heading by initially finding the most direct route to the desired goal. Next the desired heading is updated with the input from the lane heading subsystem. This takes into account the lanes up to five feet in front of DOLLE to keep DOLLE inside the course. Finally, the obstacle avoidance subsystem is used to prevent DOLLE from hitting any obstacles. The combination of these algorithms will choose to find the heading to meet the priority heading criteria while attempting to converge to the goal heading.

Flag Detection

When on the advanced course, the final obstacle is to navigate the flag section at the end. The flag detection algorithm uses three simple steps as seen in Figure 13. 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 overlaid on the GUI so that the user can immediately see what has been detected as a flag and make adjustments to code as needed.

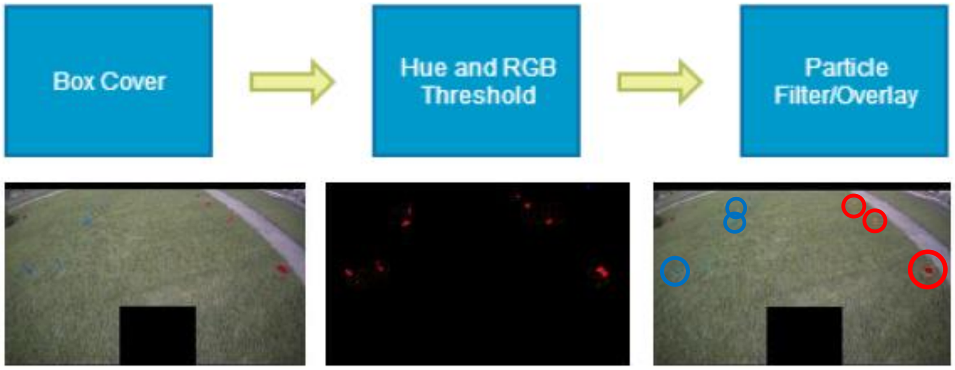

Figure 13: Flag detection process

Obstacle Avoidance

DOLLE's obstacle avoidance algorithm uses a LabVIEW function called "Advanced VFH" to create a new heading around obstacles. This function implements a use of a Vector Field Histogram (VFH) to determine location of obstacles. The LIDAR data is passed in the Advanced VFH module, and when an object is detected within 2 meters of the robot, it is classified as an obstacle. The function uses the previous heading and the values of classified obstacles to output a new heading that avoids the obstacle field.

Simulation

The simulation used to test the software is split into 2 parts: a data simulator and a system simulator.

LabVIEW

To troubleshoot issues with software a simulator was created so that DOLLE's GPS position and IMU heading could be manually controlled to observe how DOLLE would react. This program allows software to be bench tested from the lab and the team can use it to troubleshoot issue that could typically only be seen when driving the system. Not only does this save team members' time in the troubleshooting phase of software development, this also prevents hardware modifications from delaying initial software tests. The simulator can only be used when the GPS and IMU are turned off, as manual control of the GPS position and IMU heading requires that those values aren't being overwritten by the sensors or their health monitoring system. Figure 14 below shows the control panel of simulator.

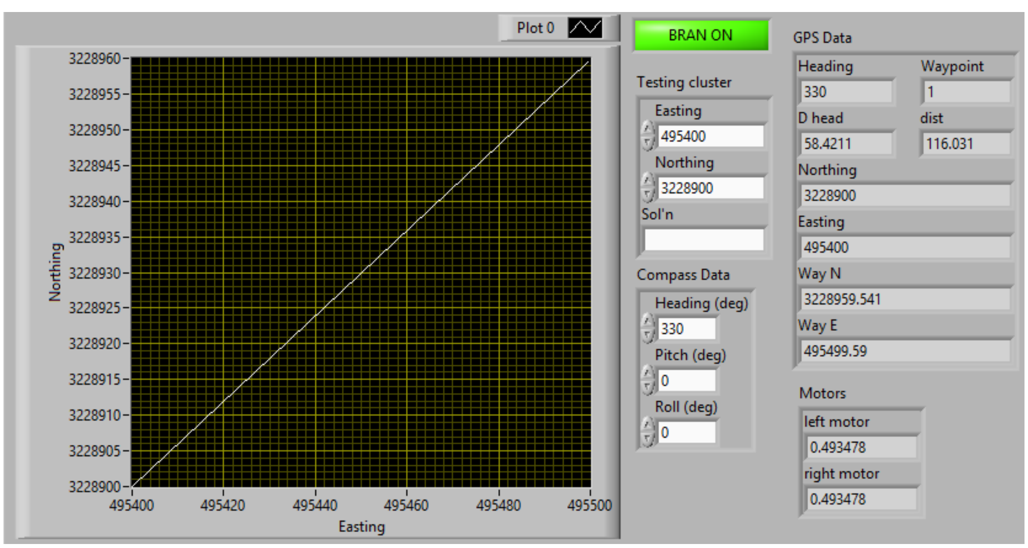

Figure 14: LabVIEW data simulator

MATLAB

The team has also developed a data logging system which gathers all sensor and algorithm information into a text file that can be later imported into MATLAB and replayed. The data logging system helps immensely with the testing and refining process by identifying problems that cannot be immediately noticed by vehicle performance inspection during a test. The output of the program is shown in Figure 15. The black rectangle represents the robot, 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, which will cause a reaction from the robot. 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, and latency. Data can be fed into the system simulator from the data simulator to observe the output of the system, which is useful in determining software issues without needing to go outside and have a test run for each new change.

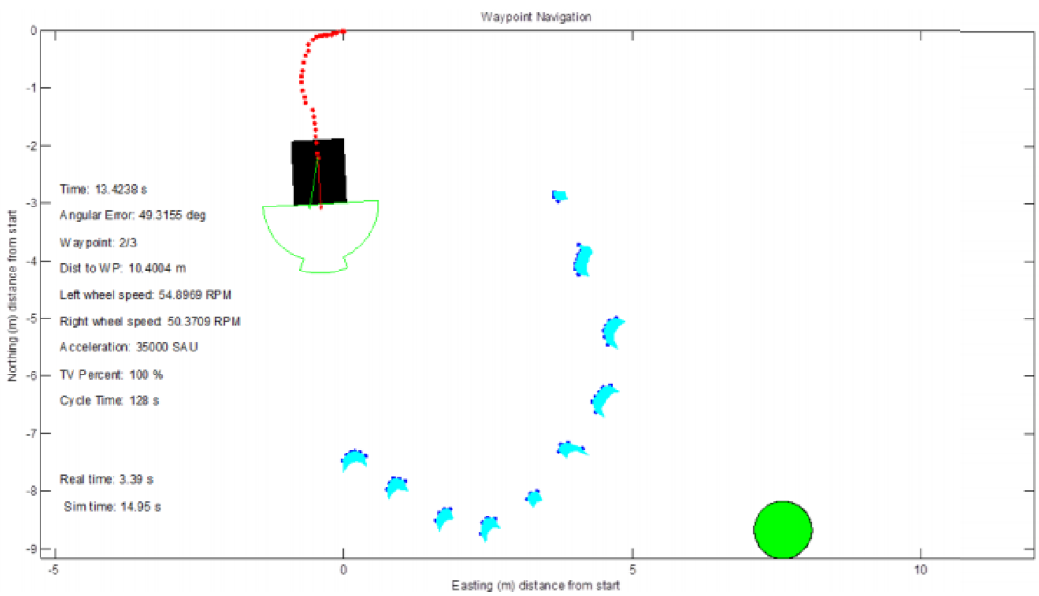

Figure 15: MATLAB system simulator

Communication

JAUS

The Joint Architecture for Unmanned Systems (JAUS) is an SAE standardized communication protocol that has been implemented in DOLLE. The Interoperability Profiles (IOPs) integrates JAUS's services to help it perform the four main IOPs: The Overarching IOP, the Communication IOP, the Payloads IOP, and the Controls IOP. The attributes that spawn from these categories are the Platform Databus Attribute, the Transport Attribute, and the Mobility Attribute. This software requires a sequence structure, which creates a timeline of events. DOLLE incorporates the Core Operability attributes and Platform Management Attributes and the Navigation and Reporting Attribute group. The first event opens the port and UDP connection to the controlling unit by connecting to the Judge Testing Client (JTC) using a special team Subsystem ID (SSID). DOLLE 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. DOLLE 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.

Failure Point Identification & Resolution Methods

Mechanical

DOLLE uses hardware components and sensors that have been used by the team in previous competitions. In order to prevent the unlikely event of hardware failure, regular testing was done to ensure their proper use. In the event of a failing sensor, a replacement sensor can be hooked up to the system with no required updates to the software. In the event that a failure occurs on the frame or on any mechanical components, the onboard toolbox has all the tools necessary to maintain working order of DOLLE.

Electrical

The wiring subsystem is all handled by industry standard connectors. The batteries are connected to the power board using XT60 connectors, and the sensors are powered from the power board using Molex connectors. These allow for quick removal when trying to diagnose connection issues. Should a connector need replacement, it is quick and easy to crimp a new Molex pin on and fit into a new connector.

Software

Health Monitoring

The software is only as durable as the communication with the sensors. Some sensors have a tendency to lose connection when connectors are jolted and/or general communication crashes. The software is constantly monitoring the sensor connections for any errors that may arise from communication protocol issues or disconnections and attempts to reset sensor connection. During the reset, the algorithms send a dummy set of data, as if the course is free, and then uses the existing feedback data to aid in temporary travel. The dummy data sends a trigger to show that the map should take over until new sensor updates occur or if the approximated location has no new data.

Vision Processing

With vision-based algorithms, the toughest part of maintaining great results is dynamic lighting impeding the detection of white lines. The physical and solar interference affect the actual image quality due to washing out the scene. The most pertinent change is the change in sunlight: the direct sunlight versus a cloudy day can change mid-run and affect the amount of luminance on the ground. The software combats the chance in sunlight issue by preparing to find a very sunny set of lines on the ground. With the dead grass and flowers in the lanes, these objects could be considered as potholes or the ramp (based on size of patches) to help filter them appropriately (based on vision algorithms) and continue navigating accordingly.

Testing

DOLLE was tested in an outside environment that was similar to the IGVC competition layout. The white lines painted on the grass with orange traffic barrels placed throughout made for a great place to test DOLLE in a pseudo- competition environment.

Before the outdoor test could be conducted, each subsystem had to pass a quality assurance check to make sure the systems were still working. Each of the sensors, being reused from last year, were checked in the lab to ensure the cables still had a good connection for both power and data.

Before physically making the new frame, it was first created as a CATIA model, where the stresses and strains on the frame could be measured and adjusted before making the first prototype. This ensured that the frame could withstand the force of the payload and computing system on top of it.

The subsystem tests were performed before each time DOLLE was tested outside to ensure no problems had arisen between tests. This allowed for problem-free tests of the software. As each software algorithm was tested, from waypoint to obstacle avoidance, a remote E-Stop, operated by a secondary team member, was always at the ready to prevent unexpected drive patterns for a safer test environment.

Conclusion

DOLLE is a fully autonomous robotic vehicle designed, manufactured, and tested by engineering students at ERAU. The DOLLE team gave special attention to both the requirements of the IGVC competition and the requirements set forth by their professors. DOLLE accomplishes the team's goals of creating a lightweight, safe, maintainable, and accessible robot with a modular design. While overall testing time was low, DOLLE will have ample time to go through more testing and fine-tuning before the 2017 IGVC competition in the summer. The team feels confident that DOLLE will not only be capable of completing both the basic and advanced practical course, but that it will also impress the judges with its intelligent and innovative design.

References

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May 15, 2017

Intelligent Ground Vehicle Competition
AUVSI Foundation

Dear IGVC Judges,

I certify that the engineering design of DOLLE, as described in the accompanying report, has been significant and is equivalent to that required of a senior design project.

Sincerely,

Eric Joe Coyle
Associate Professor of Mechanical Engineering
Embry-Riddle Aeronautical University

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