AMOS: IGVC 2019 Design Report

Multi-Disciplinary Robotics Club

Rochester Institute of Technology

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Statement of Integrity: This report is prepared by IGVC team members in Multidisciplinary Robotics Club at Rochester Institute of Technology.

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1.1 Introduction

The Rochester Institute of Technology (RIT) Multi-Disciplinary Robotics Club (MDRC) is entering AMOS into the 27th annual Intelligent Ground Vehicle Competition (IGVC). AMOS is new and improved from the last time RIT competed in the competition in 2013 and was designed to autonomously navigate the course for the competition. The design goals of the team were to create a small and maneuverable robot in order to better navigate around the obstacles and the course. AMOS utilizes sensors such as a depth camera to determine the line boundaries, a sixteen channel Velodyne LIDAR in order to detect obstacles, an IMU to determine the robot's orientation and direction, and an Nvidia Jetson TX2 functioning as our GPU and CPU. The vehicle was named after the previous vehicles from RIT that competed in the competition and was designed to be weather resistant and aesthetically pleasing. This report describes the process of designing AMOS.

1.2 Organization

Each member of AMOS worked collaboratively with each other in order to determine the potential component selections, systems, and design of AMOS. Through many discussions and meetings, all the parts and design of AMOS was agreed upon. The design of AMOS was figured out and agreed upon as a group. Due to the small size of our group, each member was delegated a major part of the robot to work on. Once the different components were ordered and arrived, a member was then put in charge of configuring the sensors, another was put in charge of path planning, and the last member was in charge of the power systems of the robot. The team captain oversaw the development of each part of the robot and made recommendations on how to solve problems that other members were having. See Table 1 below for the team's organizational chart and hours spent on the project.

IGVC Team Members

Name	Role	Standing	Major	Estimated Hours
Dylan Lebedin	Team Captain Sensor Configuration	Second Year	Electrical Engineering	220
Lance Malone	Power Systems	Second Year	Electrical Engineering Technology	192
Colin McDonald	Path Planning	Freshman	Computer Science	180

1.3 Design Assumptions and Design Process

The AMOS team assumed the course would be similar to the course seen in the Official Competition Rules. The design process for AMOS started off with determining the correct size and shape of a robot that the members thought would be a maneuverable vehicle that would help with getting the best time possible on the course. The team started from scratch and for each component that was selected, a series of discussions and reviews helped determine the viability of the components. The team member in charge of the different systems on AMOS, conducted their own research for components and once finished, were shown to the rest of the team members to determine if it would be used for the robot. As the frame of the vehicle was being decided, the team budget got an increase from a corporate sponsorship with the club. This sponsorship allowed for the team to look at better quality sensors and power systems, that would help improve our chances at the competition. The team adapted their previous design in order to make changes for the new components and determine the proficiency of them if placed on the robot. The numerous discussions the team members helped determine the best possible components for AMOS to best compete in IGVC.

2. Effective Innovations in your Vehicle Design

2.1 Innovations

The vehicle's systems had different innovations depending upon the specific system. The LIDAR and depth camera used ROS for easy integration between the sensors and software. The LIDAR used was a sixteen channel Velodyne LIDAR used for detecting objects. The ROS Velodyne package helped configure the LIDAR. The Intel Realsense d435 Depth Camera was used to lane detection. When the camera was integrated with ROS, python code was then used to create a Hough Transform on the camera in order to better help with lane detection. The team's frame design helped allow for easy access to the electronic enclosure, batteries, and payload. The acrylic panels help provide weather resistance for the electrical components, and the different mounts help reduce the vibrations the different sensors while traversing through the terrain on the course. The motor controllers used on AMOS are the Talon SRX, these motor controller can also send data such as the position of the wheels and their current velocity by reading a encoder built into the motor’s gearbox.

3. Mechanical Design

AMOS is a four-wheel drive vehicle. The small size and lightweight aluminum frame allow for greater course maneuverability. Acrylic sheets help provide weather-resistant protection and an aesthetically pleasing look to the robot.

3.1 Frame Structure (Chassis)

AMOS drive chassis is made from 8020, a material that is made of aluminum, allowing it to be lightweight and durable. The lightweight frame also allows for a reduction of work from the motors. Acrylic sheets were placed in between the beams of the 8020 in order to hold the motor controllers, electrical components, and the sensors of the robot.

3.2 Suspension

AMOS currently has no real suspension system currently in place and the motors are currently fixed directly onto the chassis.

3.3 Weatherproofing

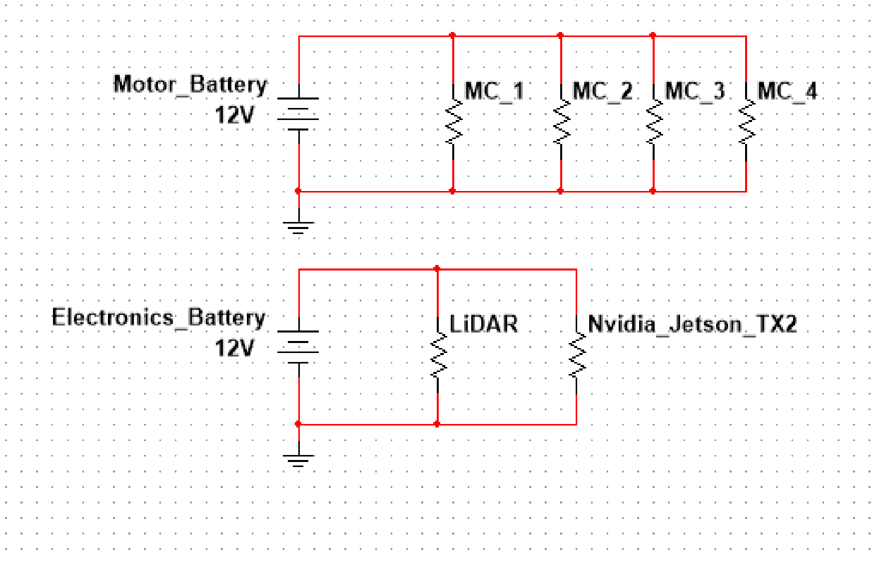
AMOS currently has acrylic sheets attached to its chassis with velcro, This will keep most forms of weather from interfering with its electrical systems by providing an almost airtight seal for them. It is recommended to not operate AMOS in the weather conditions that involve flooding however due to the air holes on the bottom of the Robot, these are needed as the Nvidia Jetson TX2 can overheat without some sort of cooling system in place.

4. Electronic and Power Design

AMOS's electrical system was made to be as safe and simple as possible so that AMOS could be easy to work on in the future, as this was a problem with previous versions of AMOS. It accomplishes this by making most things communicate and get power through the onboard Jetson TX2's USB ports, this allows for not only easy repair but is also very easily organized.

4.1 Power Distribution System

AMOS gets its power through two 12 Volt, 28 amp. hr. Batteries, that both have a recharge time of about an hour. one battery is used to provide power to the motors and their controllers the other one provides power to all sensors and to the main computer of AMOS. Through calculation, the max run time of AMOS was around 3 hours, in a real-life test however this dropped down to roughly 2.7 hours primarily due to both batteries being pretty old and general heat loss especially with the Nvidia Jetson TX2. The power system of AMOS design wise is simple, on the electronics and sensors side of the circuit only two things needed their own dedicated power hookup, the Nvidia Jetson TX2 and the Velodyne LiDAR since these two items needed the same amount of voltage they were simply put in parallel with their battery, forming something similar to a two resistor parallel circuit. On the motor side of the power system every motor and motor controller was exactly the same, so all of the motor controllers were put in parallel with their battery as well. For a visual representation of the power system see the following figure:



4.2 Electronics System

The main source for our electronics system is the Nvidia Jetson TX2, which acts as our GPU/CPU. The Velodyne LIDAR and Intel Realsense d435 Depth Camera both are able to run off the Jetson. AMOS has its own dedicated IMU board that gets power and sends its data over USB to the Nvidia Jetson TX2. All motors are controlled via their own dedicated Talon SRX and are controlled via A PWM signal sent out by the Nvidia Jetson TX2.

4.3 Safety Devices

AMOS currently has three main safety features, a wireless e-stop, a wired e-stop, and finally a safety light. The wireless e-stop is a receiver and transceiver similar to what can be seen in most radio controlled vehicles, as soon as the proper button is pressed on the transceiver the receiver send one bit of data to the Nvidia Jetson TX2 which will then turn off itself and all other peripherals of the robot. The wired e-stop is a bright red button located at the back of AMOS then when pressed will cut the main power to everything in the robot. The emergency light is an LED strip that is powered by an Arduino. The light is solid when the robot is on, flashing when the robot is in autonomous mode and turns off when the robot is off.

5. Software Strategy and Mapping Techniques

AMOS’ software can be divided into three main subtasks: environment detection, path planning, and path execution. Environment detection is the process of converting sensor data into an accurate “overhead” position in the world, with knowledge of both our pose and nearby obstacles. Path planning is the process of planning a path “through” (generally directly forward) the environment, and path execution is the process of commanding the drivetrain to follow the desired path. Each subtask is described in detail below.

5.1 Obstacle Detection and Avoidance

Our main source for obstacle avoidance was using a sixteen channel Velodyne LIDAR. The data from the LIDAR would come from configuring it with the ROS Velodyne package. The LIDAR would be able to tell us the location of the obstacles once subscribed to the velodyne points node. From there the data was used in the ROS pointcloud to laserscan package, where it was then integrated into our path planning algorithm.

5.2 Software Strategy and Path Planning

The AMOS path planning algorithm tries to place detected obstacles on a 2D overhead grid. The decision to use 2D instead of 3D means that we can use simpler path planning algorithms (like Dijkstra's), which allow us to process frames significantly faster. This solution has the potential to be supplemented with GPS information (currently unused), and to integrate with data from a mapping service in a more general application.

5.3 Map generation

AMOS uses a 2D grid, with precision down to one inch, to store data from its LIDAR / camera. We store an "obstacle area" based on the distance, angle, and cross section of the object. Each area is then given an avoidance region, which is how close the LIDAR itself is allowed to be to the object. Based on our testing, 2 feet (24 units) has proven to be sufficient. Our map visualizer / simulator also allows arbitrary obstacles to be placed with the mouse cursor, which is described in greater detail under section 7.

5.4 Goal selection and path generation

Path generation / execution was heavily inspired by the concepts in the open source library Pathfinder (JacisNonsense/Pathfinder on GitHub). The path planning algorithm returns a list of points the robot must pass through (although not a continuous path), and the path generator connects these points with smooth curves and gentle acceleration / deceleration. Specifically, we use cubic Hermite splines to interpolate between all points, and then validate that none of the returned points will put the robot too close to any obstacle.

5.5 Additional creative concepts

The AMOS software is capable of using a feature of its speed controllers referred to as Motion Magic, which allows the speed controller itself to evaluate the PID loop at roughly 1000Hz. This improved precision, and allows the main computer to spend its time on higher level course planning.

6. Description of failure modes, failure points and resolutions

6.1 Vehicle failure modes (software, mapping, etc) and resolutions

One of the most anticipated failure modes on AMOS was, quite simply, a failure to construct reliable environment data from our sensor array. We store historical world data, and can use it to assist in situations like these. Since IGVC is a relatively static course, we can assume that accurate data from a few moments ago is still accurate, although our position may have changed. By continuously tracking our position via wheel encoders, GPS, and our IMU, AMOS is able to localize itself not only within the current “frame”, but throughout historical data as well.

There was not enough hardware testing done to determine faults in the system, and therefore no resolutions were made to the power systems and sensor configuration.

7. Simulations

Our map visualizer and course planning algorithm allow for arbitrary objects to be inserted into the environment. Our development process included “fuzzing” the path planning algorithm, by randomly placing objects around the environment, to look for any abnormalities in the generated path, which are then manually reviewed. There was no simulation of the robot following a path; only the path planning itself. It was assumed (and validated via field testing) that our motor controllers and their control loops, once properly tuned, would be able to correctly follow any generated path.

8. Performance Testing and Assessment

The robot was not tested thoroughly due to time constraint. Many of our parts did not come in till the last month before the semester ended. Finishing the robot and minor testing of the power systems was all that the team could have done. The team has not yet tested the robot in conditions similar to those that will be seen at IGVC.

9. Initial Performance Assessments

The team continues to make improvements on the autonomous functionality of the robot as the competition draws closer.

10. Budget

Part		Unit Price	Quantity	Total Part Price
Velcro		$9.48	3	$28.44
IMU		$99.00	1	$99.00
Intel Realsense D-435		$190.00	1	$190.00
Gearbox plate		$10.99	1	$10.99
Gearbox		$179.91	1	$179.91
Wheel tire		$14.99	4	$59.96

Wheel hub		$29.99	4	$119.96
Screws		$0.23	100	$23.00
Nut		$0.21	100	$21.00
L Brackets		$3.67	34	$124.78
T Brackets		$7.91	4	$31.64
T Slot - 30 inch		$10.65	2	$21.30
T Slot - 34 inch		$11.81	4	$47.24
T Slot - 11 Inch		$5.14	2	$10.28
T Slot - 16 Inch		$6.59	2	$13.18
T Slot - 22 Inch		$8.33	7	$58.31
T Slot - 5 Inch		$3.40	2	$6.80
Application for IGVC competition		$300.00	1	$300.00
Velodyne VLP-16 LIDAR		$4,080.00	1	$4,080.00
Gearbox plate		$10.99	3	$32.97
Gearbox		$179.91	3	$539.73
Ring Gears		$10.00	4	$12.49
Talon SRX		$89.99	4	$359.96
Talon SRX Data Cable		$12.99	1	$12.99
Velcro		$13.29	3	$39.87
Acrylic		$153.88	1	$153.88
Nvidia Jetson TX2		$400	1	$400
			Total:	$6,977.68