FAMU/FSU College of Engineering

Department of Mechanical Engineering

Project Plan/Specifications

Team 10 Autonomous ATV

Group Members:

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CISCOR
Center for Intelligent Systems, Control, and Robotics

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Problem Statement:

CISCOR currently has multiple robotic platforms used in research ranging from bio-inspired legged walking robots to four wheel skid-steered robots. Some of these platforms are able to function outside on limited terrain types. This induces a need for a vehicle that is able to traverse many types of difficult terrains. Thus, the ATV was a clear choice for a platform to automate. Last year, actuators where installed onto the controls of the ATV. The task this year is to incorporate sensing and computer systems to interface with these actuators and develop the algorithms for autonomous motion.

- *Justification/Background:*

Research into autonomous ground vehicles is growing rapidly. There is a need for vehicles to perform tasks without any physical interaction or human control. These tasks can range from dangerous search and rescue missions to civilian vehicles driving themselves through city streets. CISCOR is currently conducting research with autonomous mobile robots with emphasis on path planning and efficiency. This same type of research is desired with a more robust system that can handle difficult terrains and obstacles, as well as normal driving situations on a paved surface. For this reason, an ATV was chosen as the new platform to develop autonomous control.

- *Objective:*

The main objective is to integrate a sensory system that will scan the surrounding environment. This data is then used to compute a trajectory for the ATV to perform waypoint navigation and road following autonomously. These sensors include Encoders, SICK laser sensors, IMU (Inertial Measurement Unit), GPS system for waypoint navigation, and possibly a stereoscopic camera. Problems including the overheating of the motor-drivers and an underpowered steering actuator will also be resolved. Waterproofing the sensors, encoders and actuators must also be done to ensure all-terrain capabilities. To assist with safety, a way to shut down the ATV remotely will be developed. A kinematic model of the system will also be developed to implement the autonomous control. All of the objectives will be finished by April 2014

- *Methodology:*

In order to deliver a fully functioning autonomous ATV by the end of April many important milestones need to be met. This will be done by assigning each student a specific task for them to work on for a majority of the project. The team consists of 3 mechanical engineering students and 3 electrical engineering students.

The first step will be for the mechanical engineers to develop concepts for the new steering system, computer cooling system, wheel encoder mounting, and laser/GPS/IMU sensor mounting. At the same time the electrical engineers will begin to research communication protocols for the sensors and become familiar with ROS (Robot Operating System) and QNX operating system. The next step will be the rapid prototyping and mathematical analysis of the mechanical systems. A dedicated computer will be installed in place of the laptop from the previous year. This will require careful wiring of the power and communication between the sensors, actuators and the computers. A kinematic model of the ATV will then be developed and used to create the high level control law for autonomous motion.

The last step will be to manufacture and test all necessary mechanical components for sensor mounting and implement the computer cooling system. Also the C coding for communication, data acquisition, and trajectory computation will be fully developed for waypoint to waypoint navigation and road following.

- *Expected Results:*

At the conclusion of senior design in April it is expected that the ATV will have all necessary sensors installed and communicating with the computers and data acquisition systems. The waypoint following will be as accurate as civilian GPS allows. The ATV will be able to traverse the environment safely without flipping and damaging itself or the surroundings. The onboard computers will also have functioning software to allow the ATV to move autonomously and reliably.

- *Constraints:*

There is a budget of approximately 1500.00 USD set aside for building material. Most of the sensors and computers are already purchased. A large hurdle to overcome will be scheduling time for all team members to work on the project at specific times. Each student has a separate and unique schedule that needs to be taken into account. The largest constraint on this project will be time. There are many objectives to complete and all of them must be met by the end of April 2014.

- *Deliverables:*

-Work Breakdown Structure (WBS)

The following is a work breakdown structure of each task than needs to be completed and the dates when the tasks are to be completed. A less explicit WBS is shown visually in a Gantt chart below that also includes task dependencies.

<u>Week 6-8:</u>

- Research QNX operating system, ROS, and Ubuntu
- Concept development of all sensor mounts
- Concept development of heat removal system
- Concept development of computer/sensor network

<u>Week 7-8:</u>

- Installation of Linux (Ubuntu) and ROS on Toughbook
- Determining the amount of heat removal

<u>Week 8-10:</u>

- Concept decision
- Concept analysis
- Cost analysis

<u>Weeks 9-10:</u>

- Driver software coding for SICK laser
- Driver software coding for GPS
- Driver software coding for IMU

<u>Week 11:</u>

- Sensory data testing
- Computer/Sensor communication testing
- Refinement of mechanical deigns

<u>Week 12:</u>

- Finalize all designs
- Driver code/communication debugging

<u>Week 13:</u>

- Order parts

- *Resource Assignment:*

-Merrick Salisbury

Merrick will be responsible for with the initial instillation of software (Ubuntu, QNX, and ROS). He will then create the software that will control the ATV to perform road following. The main sensor that will be used for the road following algorithm will be the SICK laser. There will be two of these sensors mounted on the front of the ATV, one gathering data approximately 5 feet in front of the ATV and the other about 25 feet ahead. Lester will use the data from the 25 foot sensor to create the path plan before the ATV actually reaches a turn in the road. The sensor data that is looking closer to the front will be used to orient the ATV in the middle of the road. To identify the road, a custom dirt path will be constructed with mounds lining each side of the road for the sensor to gather data from. In the event that this task is completed ahead of schedule, help will be given to other project parts as necessary.

-Omesh Dalchand

Omesh will be responsible for the instillation of software on the laptop (Ubuntu, QNX, and ROS). Once the software is running and functioning properly, he will begin to interface all sensors (SICK laser, IMU, GPS), with exception of the wheel encoders, to the computer. The wheel encoders and other encoders on the actuators output too much data for the computer so there will be a dedicated computer to handle the processing of the encoder data. This interfacing requires the correct wiring and communication protocols. For example, the SICK laser uses RS232 protocol which needs to be converted to USB for communication to the laptop. This will require modification to the driver software in order to receive data from this sensor. This will be done for all other sensors. This task is very time intensive, thus any of the other team members extra time will be used to help in this process. In the event that this task is completed ahead of schedule, help will be given to other project parts as necessary.

-Lester Kendrick

Lester will be responsible for the initial instillation of software (Ubuntu, QNX, and ROS). His main task will be writing the software that will be responsible for the autonomous waypoint to waypoint navigation. Testing data will be used initially instead of real time sensory data since the sensory interfacing to the computers will not be completed by this time. For an example, GPS data is required to know the location of the ATV so simulated GPS data coordinates will be used to test the software. The SICK laser sensors on the front of the ATV will be used to make sure no obstacles are hit during the waypoint following. Obstacle avoidance will not be a part of this project, however vehicle stopping upon detection will be included. In the event that this task is completed ahead of schedule, help will be given to other project parts as necessary.

-Michael Brazeau

Michael will be responsible for the mounting and wiring of all four wheel encoders, and mounting a new, stronger steering motor. The encoder design from the team last year included mounting a belt/pulley system from the wheel to the encoder. Since most of these parts are already purchased the design may not be changed too much due to time constraints, but necessary changes will be made to ensure proper encoder function. The current steering motor is not powerful enough to turn the wheels while the ATV is stationary on a high friction surface. This will be remedied by installing a more powerful steering motor. For both of these tasks, the necessary force calculations will be done ensuring the mounts will be structurally sound and the motor will be able to steer the vehicle properly. Cost analysis and multiple design ideas will also be constructed and one final design will be chosen using a decision matrix. In the event that this task is completed ahead of schedule, help will be given to other project parts as necessary.

-Jeremy Hammond

Jeremy will be responsible for determining and implementing a solution to the overheating problem while also mounting the IMU. At the point all of the power requirements are known for all of the electronic components that will be housed in the rear ATV trunk, Jeremy will propose multiple solutions to dissipate the required amount of energy from the box to keep the electronic components at a safe temperature. The rear trunk housing is waterproof as it stands and the final design must maintain this waterproof characteristic. The proper fluid dynamics analysis will be done to prove the system will function properly and dissipate the required amount of heat. The IMU will need to be mounted in a safe location so it will not be damaged. The IMU will also need to be mounted somewhere in the center of the vehicle for ease of calculations with the IMU data. In the event that this task is completed ahead of schedule, help will be given to other project parts as necessary.

-Marc Akbar

Marc will be responsible for mounting the SICK lasers along with the GPS system. The laser system will be mounted in front of the ATV in a position where it can accurately gather sensory data within a 180 degree sweeping range. Both lasers will not interfere with the air intake of the ATV or each other's data gathering. A protective cage may also be designed to ensure the lasers are not damaged, without interference with sensor data, due to the fact that they will be directly on the front of the vehicle and may be subject to impacts. The GPS will be mounted in a place where environmental harm is at a minimum. This must also be able to constantly receive the satellite data without any interference. Stress analysis for the design ideas and material selection will be done in both tasks to ensure the equipment's stability and function. This along with a cost analysis will be analyzed in a decision matrix to determine the most efficient design. In the event that this task is completed ahead of schedule, help will be given to other project parts as necessary.

- *Product Specifications:*

-Design Specifications

Steering Motor: A new, more powerful steering motor will be installed in place of the current motor. As of now the motor cannot steer the vehicle while stationary on a high friction surface. When the larger motor is mounted it should not interfere with any other moving steering components. A dynamic model of the ATV will be constructed and augmented with test data to help calculate the necessary torque that the motor needs to output. A FEM analysis of the mounting bracket will be done to ensure the bracket design and material will withstand the maximum torque of the motor without failure.

Heat Removal System: Once all of the power requirements are known for the computers and other electrical components inside the rear trunk, the proper fluids analysis can be done on each design proposal to determine which designs will be sufficient. This system must maintain the waterproof nature of the rear trunk to ensure the protection of the electronics. It must be secured firmly on the ATV and must not interfere with any other system such as the ATV charging system, electrical components, drivetrain, suspension, etc.

Wheel Encoders: Knowing the position of all four wheels is necessary to automate the ATV. This will be done by installing an encoder on each wheel via a belt drive. The encoders should not interfere with the drivetrain in any way. Since the encoders will be belt driven on the underside of the vehicle, care must be taken to not let any debris jam up the belts or damage the encoders. The encoders are already waterproof so moisture will not be an issue.

SICK LMS-200/GPS: Two SICK laser sensors will be mounted in the front of the ATV. These lasers will have a 180 degree scan angle with the first laser aimed 5 feet in front of the ATV and the other laser aimed at 25 feet in front of the ATV. The Robot Operating System (ROS) will be used in order to program the sensors to interact with the terrain and the movement of the ATV. The ProPak-G2 plus GPS will be used for waypoint navigation. It will be mounted in the rear trunk, connected to the Toughbook. The GPS antenna will be mounted externally to receive clear GPS signals from the satellites.

Mounts: Cost and stress analysis must be done on the mounts. The mounts must be able to withstand the stresses of the environment. They must also withstand the weight associated with the sensors. The mounts must ensure the position of the sensors will not change while the ATV is in motion. The size must be small enough as to not interfere with other components of the ATV or the sensors themselves.

Interface: The communication between the three sensors and the second computer running QNX will need to be setup. There will be two SICK LMS-200 laser connected to the computer running ROS to map the terrain. Since the computer only has one RS-232 connection, a USB to RS-232 converter will be used to connect the sensors to the computer. The ProPak-G2 plus GPS which will be used for waypoint following, will be connected by USB. There will also be wireless computer-to-computer (ad-hoc) network connection from the computer running ROS to the QNX computer. This will be the main data link between the two computers were all information from all of the sensors will be sent.

-Performance Specifications

Steering Motor: When the ATV is in operation the motor should be able to turn the handlebars to the desired location and maintain that position while the ATV is stationary and while it is moving. The motor should not overheat or break any other components. The encoder on the new motor should accurately output the correct motor position to the computers.

Heat Removal System: It is expected that this system will be able to remove enough excess heat produced by the added electrical components so as to allow them to operate at a safe temperature. Any power used will be drawn from the ATV's battery.

Wheel/Actuator Encoders: The main function of the encoders is to give a position signal to the on board computers. The Wheel encoders should output clear signals that give the position of the wheels with a high degree of accuracy and low signal noise. The same goes for the encoders on all four of the previously installed linear actuators.

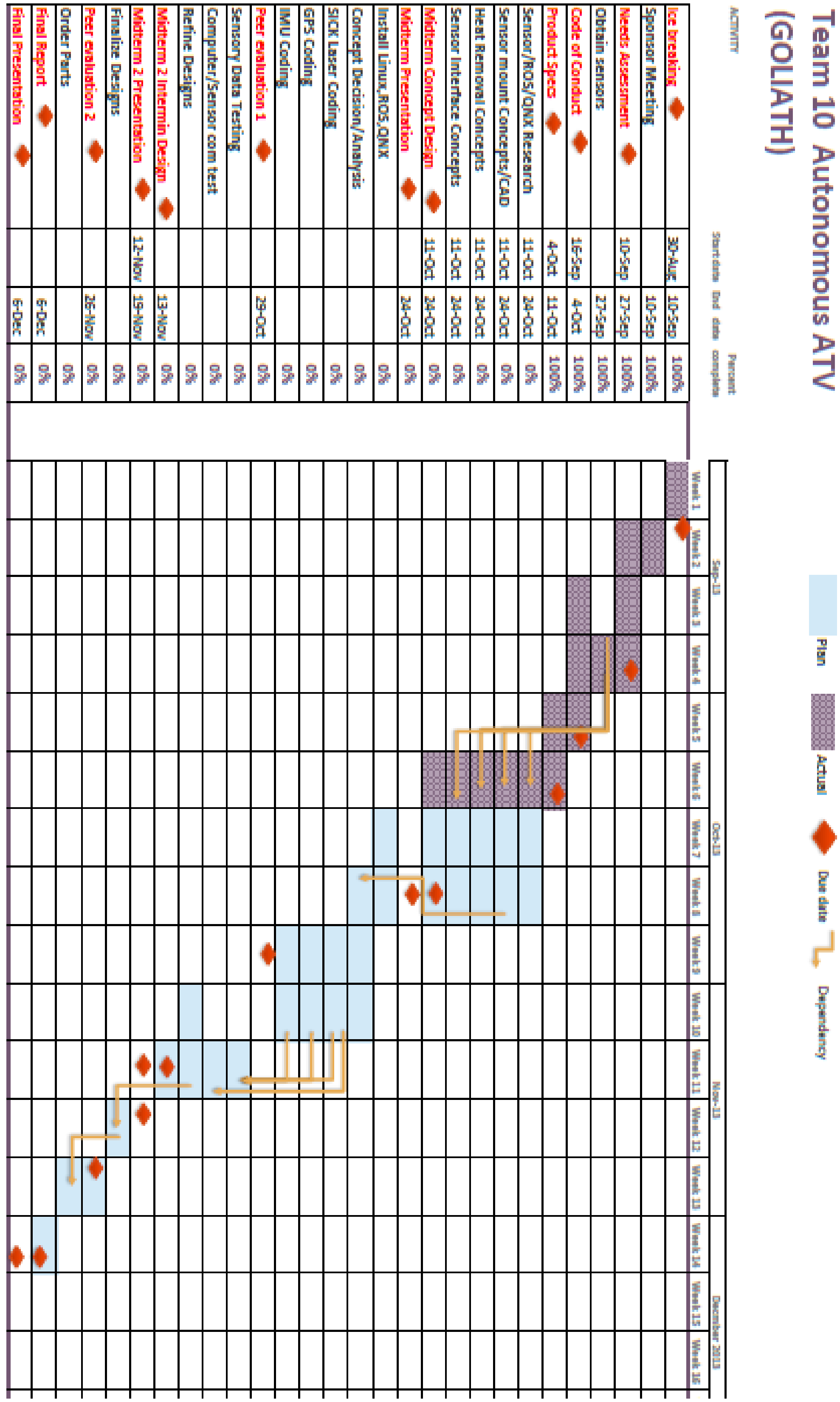
SICK LMS-200/GPS: The two laser sensors will scan continuously the terrain to search for the guided path which the ATV is to follow and for obstacles in front of the ATV so that no damage is done to the ATV or anything surrounding it. The sensor pointed at 25 feet in front of the ATV will let it know of upcoming path variances and possible obstacles while the sensor aimed 5 feet in front of the ATV will give it the path outline and possible obstacles immediately in front of itself. The GPS will output accurate location of the ATV to the computer with reasonable accuracy.

Mounts: The mounts will secure the position of the sensors without compromising the integrity of the ATV or the functionality of the sensors. They will be made to withstand any weathering or forces that may be involved in testing.

Interface: The data acquired by the laser will be available in real-time to the system and the ATV will be able to see its surroundings. The data acquired by the GPS will also be available letting the ATV use waypoint following.

Overall: All of the new sensory equipment, computers, and wiring should be secure, and not interfere with any other components or functions of the ATV. With all of the added equipment the ATV should still remain drivable by a human. When the project is finished, the ATV should be able to perform autonomous waypoint navigation and road following.

- *Gantt Chart*



Team 10 Autonomous ATV (GOLIATH)
Plan
Actual
Due date
Dependency
ACTIVITY
Start date
End date
Percent complete
Sep-13
Oct-13
Nov-13
December 2013
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
Week 12
Week 13
Week 14
Week 15
Week 16
Ice breaking 30-Aug 10-Sep 100%
Sponsor Meeting 10-Sep 100%
Needs Assessment 10-Sep 27-Sep 100%
Obtain sensors 27-Sep 100%
Code of Conduct 16-Sep 4-Oct 100%
Product Specs 4-Oct 11-Oct 100%
Sensor/ROS/QNX Research 11-Oct 24-Oct 0%
Sensor mount Concepts/CAD 11-Oct 24-Oct 0%
Heat Removal Concepts 11-Oct 24-Oct 0%
Sensor Interface Concepts 11-Oct 24-Oct 0%
Midterm Concept Design 11-Oct 24-Oct 0%
Midterm Presentation 24-Oct 0%
Install Linux,ROS,QNX 0%
Concept Decision/Analysis 0%
SICK Laser Coding 0%
GPS Coding 0%
IMU Coding 0%
Peer evaluation 1 29-Oct 0%
Sensory Data Testing 0%
Computer/Sensor com test 0%
Refine Designs 0%
Midterm 2 Intermin Design 13-Nov 0%
Midterm 2 Presentation 12-Nov 19-Nov 0%
Finalize Designs 0%
Peer evaluation 2 26-Nov 0%
Order Parts 0%
Final Report 6-Dec 0%
Final Presentation 6-Dec 0%

References

1) sicktoolbox.sourceforge.net LMS-200 datasheet

2) www.novatel.com Propak G2 plus