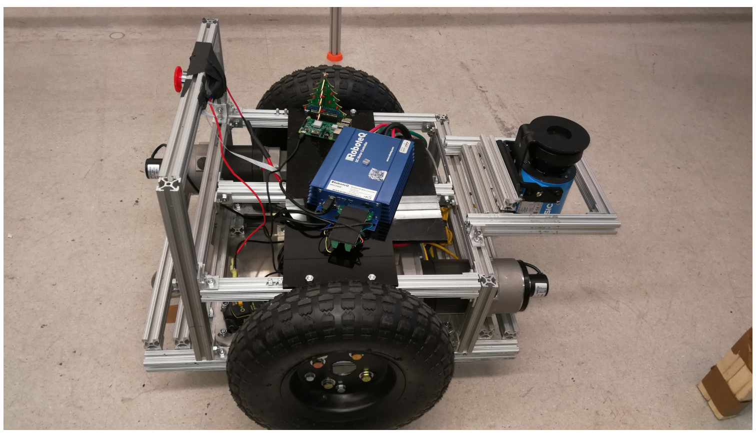
Department of Computer Science & Engineering
The University of Texas at Arlington

Project Charter
Senior Design
Summer/Fall 2017



Team UGV
Unmanned Ground Vehicle

Paul Asyn
Chris Collander
Chase Huffman
Darrell Rasco

Revision History

Revision	Date	Author(s)	Description
0.1	06.27.2017	Chris	document creation and initial editing
0.2	06.29.2017	Chris	wrote related work
0.3	06.29.2017	Chase, Chris	wrote background
0.4	06.30.2017	Chris	wrote vision, mission, and success criteria
0.5	07.01.2017	Paul	wrote equipment
0.6	07.02.2017	Paul	wrote preliminary budget
0.7	07.02.2017	Darrell	wrote system overview
1.0	12.07.2017	Chris	finalized document

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1 Vision

The vision of the team is to create a ROS-enabled payload transportation robot for use in distributed robotic systems. This robot should be able to move as far a distance as possible while still staying in range of the WiFi access point with proper safeguards and be able to be controlled through a centralized network with other robots.

2 Mission

Distributed robotic networks are used in military applications and factories worldwide. Multiple robots communicate between each other through either a centralized or decentralized network. These robots can be of multiple types including UAVs, UGVs, robotic arms, or humanoid robots. These systems may interact with one or more human operators as well.

One common form of robot in these distributed networks are payload transport robots. These robots are designed to move items between any combination of robot and human operators.

The way the team will achieve the vision is with an Unmanned Ground Vehicle (UGV), which could also be referred to as a robotic table. The UGV will use a square frame design with a wheel on each side for stability and easy maneuverability. Two opposing wheels will be controlled with motors while the other two wheels will be on free-spinning axles with omnidirectional wheels to allow forward motion. In this configuration the UGV will be able to move forwards, backwards, and rotate in place.

The UGV will utilize a spinning LiDar with Hector SLAM for environment recognition and navigation. ROS (Robot Operating System) will be used to control the robot due to ROS's broad use in industry with many robots, allowing easy interfacing. The UGV software will consist of one ROS package. One ROS Node will publish the LiDar data while another ROS Node will subscribe to motor speed messages. This configuration will allow ROS nodes either on-board or externally through WiFi to control the UGV and other robots.

A simulated version of the UGV will be created in ROS-Gazebo to allow proper testing, verification, and validation of UGV behavior.

3 Success Criteria

The test of success will be to complete the sequence of events as listed below.

- The UGV will power on and start the ROS Core and the ROS Nodes for the UGV as well as configuring the LiDar
- The external PC software will connect to the ROS Core of the UGV
- The external PC software will create a thread to subscribe to the LiDar data topic and create a dynamic map of the environment that can be displayed on the PC monitor with the location of the UGV
- The external PC will process the information of the environment and repeatedly publish the correct motor speeds to the UGV to navigate to another point in the environment.

4 BACKGROUND

This project stems from the desire to have a transportation device that will transfer items between a combination of robots and humans for human-robot collaborative systems. The fundamental flaw with the robotic arm in the Senior Design lab is that it is stationary and can only pick up and move items within the direct vicinity. Robotic arms and human operators may not always be within arms reach of each other which makes transportation of objects between the two difficult. Our project and design will allow robotic arms to transfer items to another destination within a room without any human interaction.

Chris Collander came up with this idea while working with robotic arms at UTA. Chris has been fascinated with robotics since a young age and Chris felt this project would satisfy his desire to build his robot and continue his work in human-robot interaction. While Chris has experience making small remotely controlled UGVs, none has approached this level of complexity.

Chris and Darrell Rasco have known each other for years as they are both computer engineering students. Darrell wants to work with robotics when he graduates from college, specifically in the field of advanced prosthetics or assisted living robotics. This project encompasses many of the skills that Darrell will need when he pursues his interests in the professional world.

Darrell met Chase Huffman in a computer networks course in the summer of 2017. Chase's has a strong passion for machine learning, computer vision, and unmanned vehicle systems. This project would offer the encouragement Chase needs to become well versed in these areas before he graduates.

Chase met Paul Asyn one year previously, and they had planned to be in the same senior design group. Paul makes a living as a freelance photographer and has always been interested in working with pictures and images. Paul's interests in these areas extend to the field computer vision in addition to robotics. Paul intends to use this project to work in these regions in addition to learning to interface between hardware and software.

This project stemmed from Chris's initial idea of a transportation medium between a combination of robots and humans and evolved with the topics that the team was educated in as well as topics that the team wanted to learn such as computer vision and machine learning.

5 RELATED WORK

Many UGV's have been created in the past for a very large number of reasons. Since this project focuses on a slow-moving trajectory-following UGV for collaboration with industrial robotic arms this section will refer only to similar work.

In 2002 the MATILDA robotic platform was created with a focus on payload transportation. This robotic platform was able to carry a maximum payload of 125 lbs and it could tow a maximum weight of 475 lbs. The maximum speed was two mph with a mean operating time of two hours [3].

In 2004 the iRobot PackBot was created for military applications in payload recovery, transportation, and delivery. One large feature was the ability for the PackBot to be transported as pack strapped to the back of a military soldier. The wheel system was made to be able to traverse terrain as uneven as a set of stairs [4].

Amazon has been using robots in their warehouses recently. These bots move around the warehouse to a destination shelf, lift the shelf similar to a car jack, and move the shelf to the desired location. These robots are low-form factor, high payload robots but cannot handle rough terrain. When they are not being used they return to automated chargers which means their batteries do not need to be of a very large capacity. These robots are very similar to the goal of this current project. In 2017 Amazon started a competition for colleges and teams to create robots that could be used in their warehouses. [2].

6 SYSTEM OVERVIEW

The UGV will be implemented with a square frame chassis with a wheel on each side. The two drive wheels will be solid heavy duty wheels placed on opposite sides while the other two wheels will be omni-directional and used as idlers. This design will give the UGV a great combination of stability and maneuverability, it will have weight distributed evenly to every side and will be able to easily drive forward or reverse and rotate in place for minimum disruption to the payload and the surrounding environment.

The dimensions of the UGV will be approximately 2x2x2 ft. This will be provide a reasonable area and height for the top payload support. The top surface will be a few inches higher than 2ft due to the thickness of the wood and the added height from the wheels. This will fit with standard table heights which fall in a range of 22in to 30in [1]

The full hardware system diagram can be seen in Figure 1 while the full software system diagram can be seen in Figure 2.

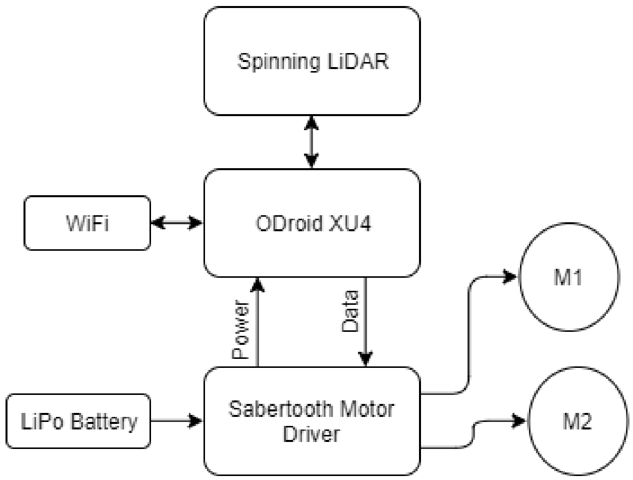

Figure 1: Hardware System Diagram

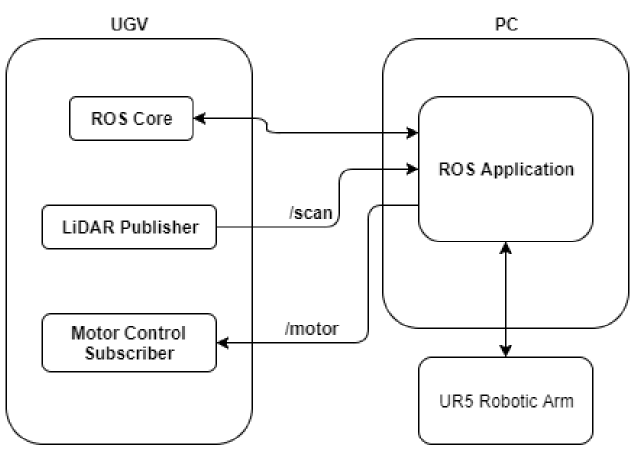

Figure 2: Software System Diagram

The drive wheels will be driven by high torque gear motors using a 100:1 gear ratio planetary gearbox providing an 84 rpm output with a peak torque of 1,347.1 oz-in. This will result in a theoretical maximum velocity for the UGV of 17.6 inches per second. The motors will be powered by a dual channel Sabertooth regenerative motor driver, which will be supported by a 10,000mAh 14.8V Lithium Polymer battery pack. A Neato XV-11 LiDAR will be used for environment detection which will include obstacle avoidance and path-planning assistance. The motor driver and LiDAR will be controlled by an ODroid XU4 which will be communicating with the PC over WiFi. It is very possible that a 9 degree-of-freedom (DoF) inertial measurement unit (IMU) will be attached to the ODroid as well.

The UGV will host a ROS-Lunar core as well as a ROS publisher for LiDAR data and a ROS subscriber for motor control commands. The PC will host a ROS application that will communicate through the ROS Core on the UGV to the LiDAR publisher and Motor Control subscriber. This software will evaluate the LiDAR data using an algorithm similar to Hector SLAM, process the environment, and send Motor commands back to the UGV in a closed loop system. In later iterations, the PC software will communicate with the UR5 robotic arm to provide commands for manipulating payloads. If the 9-DoF IMU is implemented, this information will be used by the Hector SLAM algorithm to better improve the understanding of the environment.

7 Roles & Responsibilities

Chris and Darell will be working on the electronics and mechanical design of the robot. This task will encompass finding the right parts for an effective design while remaining under budget. In addition to the design, Chris will also be setting up the ROS code on board the UGV. Chase and Paul will be working specifically with the ROS coding on the PC that will process the images from the camera feeds, and publish the correct motor speeds back to the UGV. While the roles and responsibilities of the team members are well defined, no team member will be confined to their role. We will be completing this project as a team, so there will be overlap between team members of roles and responsibilities.

8 Facilities & Equipment

Facilities to use:
- Senior Design Lab
- Engineering Research Building

Equipment:
- General Tools
- Plywood Saw
- Laser Cutter

9 Cost Proposal

9.1 Preliminary Budget

Please see Table 2 for the Preliminary Budget.

9.2 Current & Pending Support

Computer Science and Engineering Department - Senior Design budget - 800.00

10 Documentation & Reporting

In this section, you will describe all of the various artifacts that you will generate and maintain during the project lifecycle. Describe the purpose of each item below, how the content will be generated, where it will be stored, how often it will be updated, etc.

Table 2: Preliminary Budget

Item Name	**Qty.**	**Amt.**	**Tot.**
84 RPM HD Premium Planetary Gear Motor	2	39.99	79.98
Sabertooth 2x32A Motor Driver	1	124.99	124.99
ODroid XU4	1	59.00	59.00
Wifi adapter	1	18.00	18.00
64GB eMMC Module XU4 Linux	1	62.50	62.50
Multistar High Capacity 10000mAh 4S 10C Multi-Rotor Lipo Pack	1	58.39	58.39
Neato XV11 LiDar	1	0	0
4" Omni Wheel	4	9.99	39.96
4" Heavy Duty Wheel	2	6.99	13.98
Actobotics X-Rail 24"	8	5.99	47.92
1/4" Bore Side Tapped Pillow Block	4	6.49	25.96
1/4" Bore Bottom Tapped Pillow Block	2	5.99	11.98
3in Aluminum Channel	4	3.99	15.96
32mm Bore Bottom Tapped Clamping Mount	2	6.99	13.98
Clamping D-Hubs (Tapped), 0.770" Pattern, 1/4"	4	6.99	27.96
Clamping Shaft Couplers, 0.25"-6mm	2	4.99	9.98
1/4" Stainless Steel D-Shafting, 2.75"	2	1.89	3.78
1/4" Stainless Steel D-Shafting, 1.5"	2	1.29	2.58
Steel Clamp Collar, 0.25"	4	4.80	19.20
Double X-Rail Mounts (2-Pack)	16	2.99	47.84
90° Flat Pattern Bracket A	8	2.49	19.92
90° Single Angle Pattern Bracket	4	1.59	6.36
Hardware Pack (bolts)	1	10.99	10.99
Total			**721.21**

10.1 Project Charter

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10.2 Product Backlog

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10.3 Sprint Planning

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10.3.1 Sprint Goal

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10.3.2 Sprint Backlog

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10.3.3 Task Breakdown

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10.4 Sprint Burndown Charts

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10.5 Sprint Retrospective

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10.6 Individual Status Reports

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10.7 Engineering Notebooks

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Figure 3: Example sprint burndown chart

10.8 Closeout Materials

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10.8.1 System Prototype

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10.8.2 Project Poster

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10.8.3 Web Page

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10.8.4 Demo Video

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10.8.5 Source Code

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10.8.6 Source Code Documentation

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10.8.7 Hardware Schematics

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10.8.8 CAD files

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10.8.9 Installation Scripts

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10.8.10 User Manual

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References

[1] How to pick the right end tables for your sofa, March 2013.

[2] Arjun Kharpal. Amazon is offering $250,000 to a team that invents a robot for its warehouses, May 2017.

[3] Steve Munkeby, Don Jones, George Bugg, and Kathryn Smith. Applications for the matilda robotic platform. In *Proc. SPIE*, volume 4715, pages 206–213, 2002.

[4] Brian Yamauchi. Packbot: A versatile platform for military robotics. In *Proc. SPIE*, volume 5422, page 229, 2004.