UCF Senior Design I: Divide and Conquer

MAC: Modular Autonomous Cart that Assists with Intra-home Object Transportation

Department of Electrical Engineering and Computer Science
University of Central Florida
Dr. Lei Wei, Dr. Samuel Richie

Group 8

Brandon Silva	Computer Engineer	brandon.silva209@knights.ucf.edu
Justin TenEyck	Computer Engineer	jteneyck@knights.ucf.edu
Lisian Shehu	Computer Engineer	lisianshehu08@knights.ucf.edu
Trevor Taulien	Electrical Engineer	trevortaulien@knights.ucf.edu

Table 1. Group Information

Table of Contents

Project Narrative

Modern homes are now filled with smart-devices intended to automate and improve the day-to-day life of people. Robots are also making headway in the smart home market with products such as the Roomba being able to traverse through homes as it vacuums. With an ever growing and competitive market, we believe there is an opportunity to build a robotic system to improve daily home life for the elderly and people with disabilities. As of 2014, approximately 26% of eldlerly live alone and as of 2016 1 in 4 of adults in the US live alone with a disability including mobility, cognition, hearing, vision, independent living and self-care according to the CDC. A disability that inhibits mobility is actually most common affecting 1 in 7 adults. This project aims to build a robotic system that will be geared for easing the transportation of home objects such as laundry, groceries or small furniture items within the home.

The two key components of the MAC are that it is to be modular and autonomous. The modular component of the robot will allow the user to interchange different storage structures such as a rack for smaller items such as groceries or a larger storage basket for bigger items that can include laundry or small furniture. The MAC will also be able to follow the user to their desired destination so that it is available to help at any time the user sees fit. Since the MAC is geared towards improving daily living of the elderly and people with disabilities, there is a focus on making it easy to use, durable and robust. Ease of use requires having an interface that is simple such as a remote control with minimal buttons to command the system. The system needs to be robust so that it is able to handle loads of various weights and shapes. Finally, the system will be built to be durable to take any hits or drops as it is navigating through a household. These are the main project constraints that will drive both the hardware and software design of the system.

The design and features of the MAC will be based on the project goals and constraints outlined above. A key feature is that the user will be able to use a remote to call on the MAC to follow them to their desired destination within the home while doing its best to avoid any obstacles. In order to ensure that the load stays safely on the MAC, there will be guard rails and grip tape to hold objects in place. Many homes contain one or two steps or inclines such as the door leading to the garage. For now, the robot will come with a separate traversal ramp that can be placed by the user so that it is able to traverse any of these small inclines inside a home. The MAC will not be designed to traverse or scale steeper inclines such as stairs. For the movement of heavy objects, we will be investigating two possible methods. One option is to deploy a ramp automatically that can be used to slide objects on the loading platform. The other option being considered is to use a pallet-jack like design that can lower to pick up objects and then lift for transportation. Sensors such as motion, weight and tilt sensors will be used to keep the MAC from hitting any household objects, prevent the user from overloading the robot and to detect any unbalanced loads respectively. These sensors are intended to make the MAC safe to use as well as guarantee the load being carried. The MAC will contain a 4-wheel standard drivetrain, allowing the robot to turn in-place, keeping high traction on surfaces without damaging the surface itself, providing increased stability carrying a load, and compact in terms of the implementation of the wheels, motors and gears. A mecanum or omnidirectional drive train was considered and will be further investigated. A mecanum drive train would give the robot better mobility by allowing for positional strafing but at the expense of less stability, it will not be able

to handle as much weight as a standard drivetrain and it is more prone to damaging floors due to the shape of the wheels.

The MAC will be designed and built to ease the stress of transporting heavy objects in the house, especially for eldelery users and users with disabilities. It was of the utmost importance to consider not only how the system will operate but also how it can operate in a manner that is safe, reliable and easy to use. A user will be able to remotely command the MAC to follow the user to their destination, place a load using the various storage methods and finally call on the MAC to follow them to their final destination where they can unload whatever they decided to transport. The MAC will offer a solution that will improve daily living as well as prevent any serious injuries in heavy lifting.

Requirements

Since MAC will be designed for home use, there are requirements we must meet in order for it to be viable for home use, and further viable for those who are old or disabled. Most automated carts are used in business or industrial settings, so as there are not many available for home use, we must ensure our requirements are made with respect to the target audience. These numbers below are estimated from measurements of our own homes and typical use cases (Table 2).

Requirement	Specification	Value	Unit
Size	Robot needs to fit inside and maneuver in standard homes / apartments	2.5' x 3' x 3'	Feet^3
Durability	Robot needs to take hits, bumps, spills, items being dropped on it, and possibly being knocked over	Handle 150 pounds dropped on it, IP54 for electronics compartments	Weight, IP
Ease of Use	Robot has a remote with clearly labeled and easy to press buttons, including an onboard panel with readouts on power, battery and efficiency	One remote or single onboard panel	Controllers
Cost	Robot should be priced so middle income users can afford it	$1,000	USD
Battery Life	Robot should be able to last through normal use without dying	15 minutes at 100 pounds, 30 minutes at 50 pounds, 1 hour for 25 pounds, and 2 hours for 0 pounds	Time to load
Charging Time	Robot should fully charge in a reasonable amount of time	6 hours	Time
Weight Load	Robot should handle a max load that can handle most use cases	100 pounds	Weight
Speed	Robot needs to be slow to ensure saftey of user and environment	3 feet / second when traveling, 2 feet / second when following user Lifts at 2 inch / second	Feet per second Inch per second
Range of Remote Control	Robot needs to communicate with user anywhere in the home	200 feet from wireless access point (depending on power of WAP)	Feet
Stopping Distance	Robot won't ever travel fast, but it needs to be able to stop quickly for safety	6	Inch
Intelligence	Robot will utilize multiple sensors to plan paths when traveling, replan when necessary, return to dock automatically, and process everything on board	Path planning done in 5 seconds, replanning done in less than one second, responds to obstacles in less than 100 milliseconds	Time

Table 2. Requirement Specification

Block Diagrams

The software (Figure 2) and hardware (Figure 1) block diagrams shown below demonstrate the functionality we are planning for the MAC.
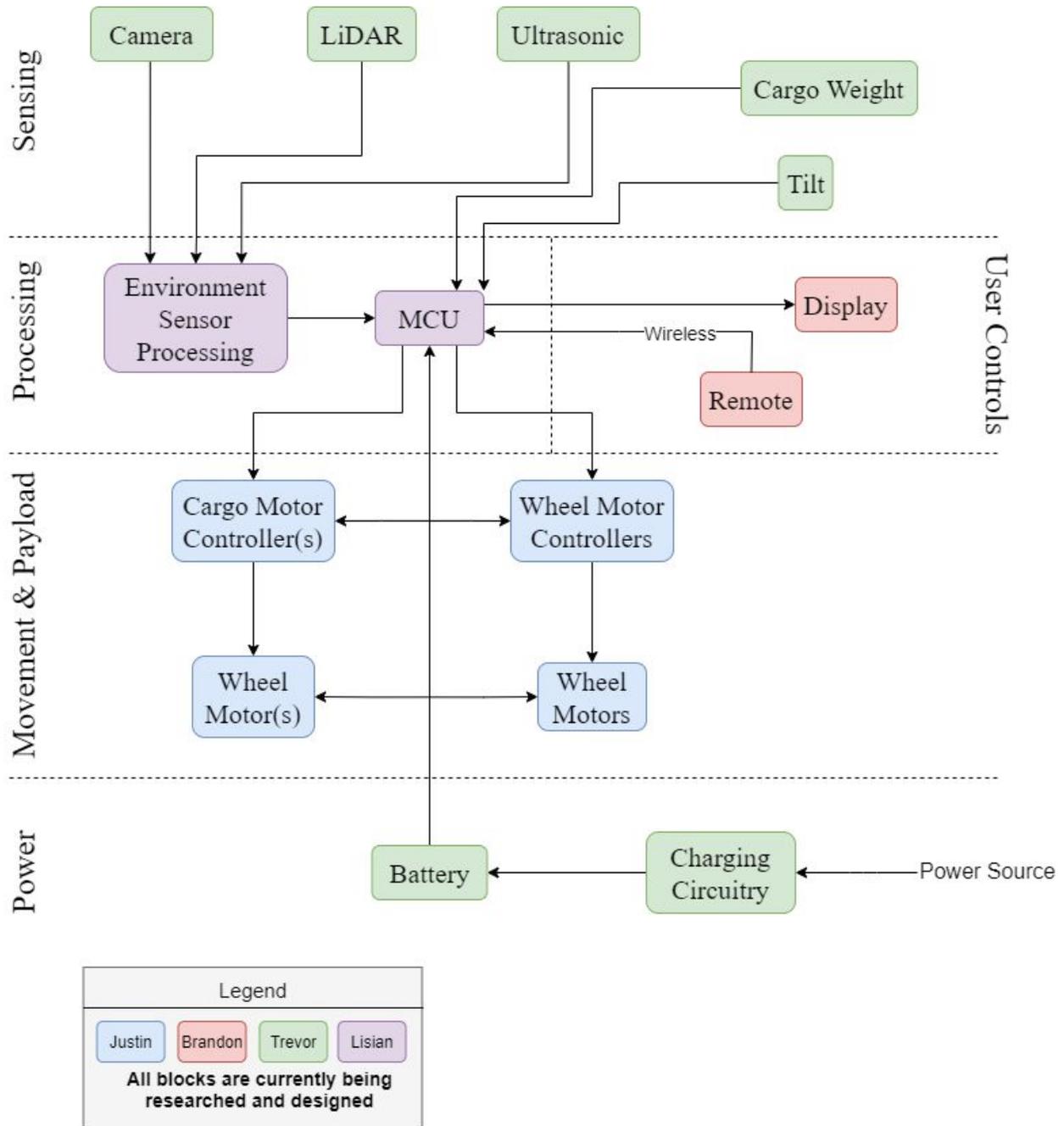
Hardware Block Diagram

Figure 1. Hardware Block Diagram
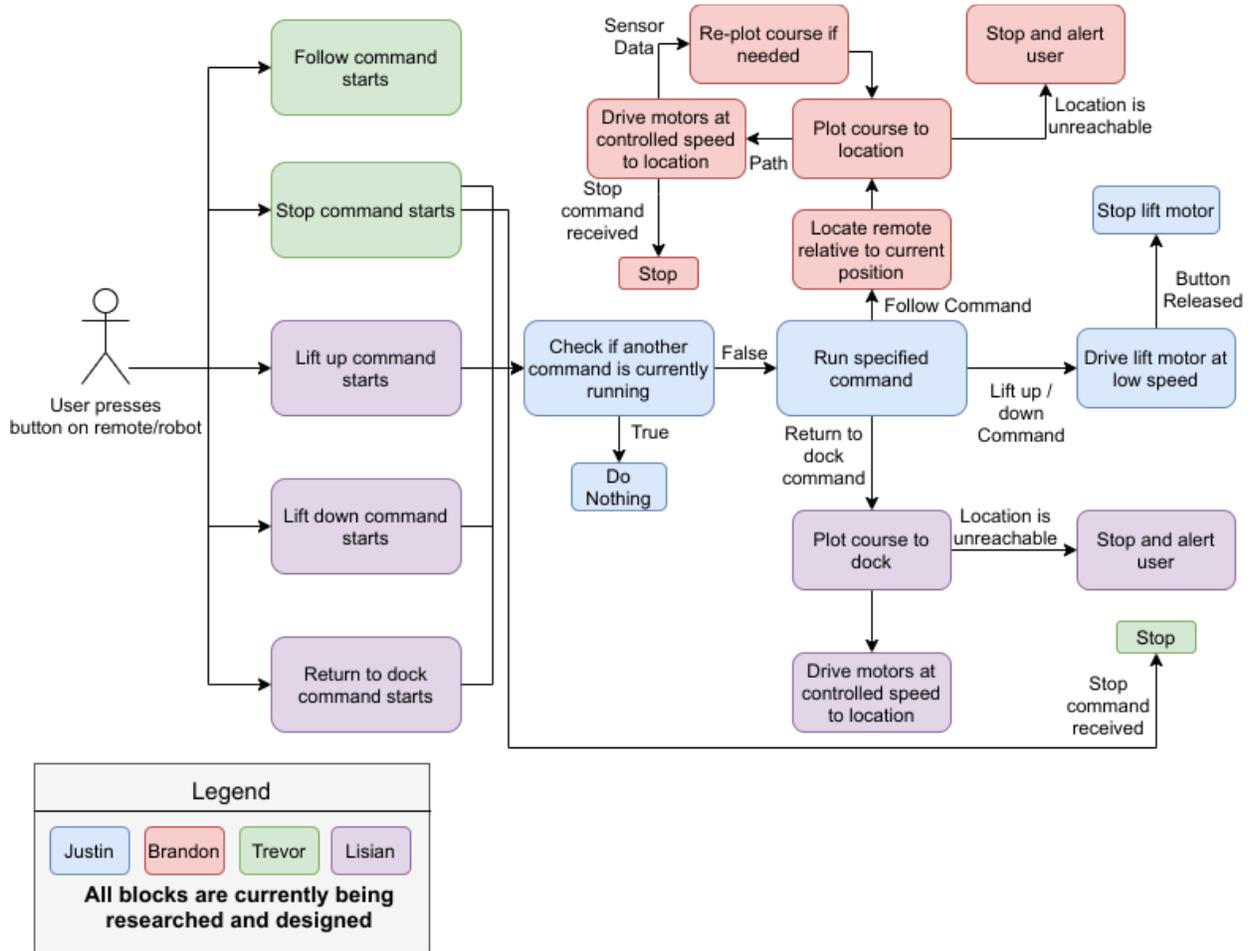
Software Block Diagram

Figure 2. Software Block Diagram

Budget and Financing

MAC is the first robot of its kind, being designed for home use, that being said we chose an arbitrary budget of $1250 based on current prices of the parts needed to accomplish our must have features (Table 3). We also researched prices for the nice to have features if and when we decide to implement them. Prices are assuming MAC will be built to full size. There are currently no sponsors for this project, and the group has agreed to fund the project.

Importance	Description	Price Per Unit Estimate ($)	Quantity	Total Estimate ($)
Must Have	Chassis Materials	150	1	150
Must Have	Chassis Hardware	50	1	50
Must Have	Cargo Lifting Motors	75	2	150
Must Have	Cargo Lifting Motor Controllers	25	1	25
Must Have	Cargo Lifiting Mechanical Components	75	1	75
Must Have	Wheels	10	4	40
Must Have	Drivetrain Mechanical Components	75	1	75
Must Have	Battery	100	1	100
Must Have	Wheel Motors	75	2	150
Must Have	Wheel Motor Controllers	25	2	50
Must Have	MCU	50	1	50
Must Have	Camera	50	1	50
Must Have	LIDAR	150	1	150
Must Have	Ultrasonic Sensor	40	5	200
Must Have	Cargo Weight Sensor	30	1	30
Must Have	Remote Electronics	20	1	20
Must Have	Remote Enclosure	10	1	10
Must Have	Ramp Materials and Hardware	30	1	30
Must Have	Shelf Materials and Hardware	30	1	30
Must Have Total:				1405
Nice to Have	Tilt Sensors	10	1	10
Nice to Have	Cargo Sorting Rails	25	1	25
Nice to Have	Docking Station Electronics	30	1	30
Nice to Have	Docking Station Enclosure	20	1	20
Nice to Have	Onboard Display	15	1	15
Nice to Have	Omnidirection Wheels	30	4	120
Nice to Have Total:				220
Grand Total:				1625

Table 3. Budget Table

Project Milestones

Number	Task	Start	End	Status	Responsible
1	Project Ideas and Selection	01/21/21	01/24/21	Completed	Group
2	Project requirements, constraints and risks	01/24/21	01/29/21	Completed	Group
	Project Documents				
3	Divide & Conquer v1.0	01/26/21	01/29/21	In Progress	Group
4	Divide & Conquer v2.0	02/02/21	02/12/21	Not Started	Group
5	60 page Documentation Draft	02/12/21	04/02/21	Not Started	Group
6	100 page Documentation Report	04/03/21	04/16/21	Not Started	Group
7	Final Report	04/17/21	04/27/21	Not Started	Group
	Research and Design				
8	Initial Modeling	02/01/21	02/12/21	Not Started	Justin
9	Drive Train	02/15/21	03/15/21	Not Started	Group
10	Chassis	02/15/21	03/15/21	Not Started	Group
11	Software	02/25/21	03/25/21	Not Started	Multiple
12	PCB Layout and Hardware	03/01/21	04/01/21	Not Started	Trevor
13	Ordering and Verify Parts	04/01/21	04/31/21	Not Started	Group
14	Prototype	TBA	TBA	Not Started	Group
15	Testing	TBA	TBA	Not Started	Group
16	Improve Design and Functionality	TBA	TBA	Not Started	Group
17	Final Testing	TBA	TBA	Not Started	Group
18	Peer Presentation	TBA	TBA	Not Started	Group
19	Final Report	TBA	TBA	Not Started	Group
20	Final Presentation	TBA	TBA	Not Started	Group

Table 4. Project Milestones

For our project, we plan to start ordering parts and getting ready to build before the end of May (Table 4). Since this project requires mechanical, electrical, and software design, we need to start as soon as possible to ensure we deliver on our requirements. The project should be modeled and designed by April first, with the final report being done by April 27th.

Trade Off Decision Matrix

Project Ideas							
Factors	Cost	Familiarity	Size	Ease of Use	Utility	Interest	**Total Score**
Weight	3	2	2	3	2	3	
MAC (current)	2	3	2	4	5	5	53
Robot Pressure Washer	4	4	3	3	3	3	50
Note: Ratings given for each category on a scale of 1 (lowest) to 5 (highest)							

Table 5. Trade off Matrix

The decision matrix above identifies two potential projects our team has considered during the initial phases of this project: MAC, the current project, and an automatic robot pressure washer (Table 5). We weighted each of the categories considered based on their perceived importance by the team. In either case, factors such as sponsorship or time are neglected given both projects are not subject to sponsorship nor any more or less complex than the other. Instead, we chose to consider cost, ease of use to the customer and interest in the project generally to be more important, followed by familiarity, size and utility.

While the robot pressure washer ended up being less costly, was more familiar based on general idea and was certainly smaller in size, the MAC had an overall better ease of use, more utility and generally was received more enthusiastically by the team as a whole. Both have come close in total score based on weight of the categories above, but overall we are leaning towards continuing on with the MAC. Some issues will need to be addressed such as cost, scale and complexity, but we do find that the current project chosen will overall make for a better end product.

House of Quality

		Size	Durability	Ease of Use	Cost	Battery Life	Charging Time	Weight Load	Speed	Range of Remote Control	Stopping Distance	Intelligence
		-	+	+	-	+	-	+	+	+	-	+
1) Ease of Use	+	↑		↑↑	↓	↑	↑	↑	↑	↑↑	↑	↑↑
2) Durability	+		↑↑		↓	↓		↑↑	↓			
3) Lifespan	+		↑↑		↓↓			↑	↓			↑
4) Cost	-	↑	↓	↓	↑↑	↓	↓	↓↓	↓	↓↓	↓	↓↓
Targets for Engineering Requirements		≤ 2.5' x 3' x 3'	≥ 150 lbs of vertical force, IP54	1 remote, 1 onboard display	≤ $1000	15 min at 100 lbs, 30 min at 50 lbs, 60 min at 25 lbs, 120 min at 0 lbs	≤ 6 hrs	≤ 100 lbs	3 ft when traveling, 2 ft when following, 2 in/sec lifting	≤ 200 ft	≤ 6 ft	Path planning ≤ 5 sec, replanning ≤ 1 sec, responds to obstacles ≤ 100 ms

Table 6. House of Quality

Our House of Quality portrays marketing requirements (row) versus engineering requirements (column), the targets for those requirements listed at the bottom of the chart (Table 6). Our marketing requirements are that the MAC should be easy to use for people of all ages and abilities, tough enough to withstand the wear and tear of daily, continuous use, last for multiple years requiring little maintenance, and be affordable to a larger portion of our target market.

Bibliography

1. "By the Numbers: Older Adults Living Alone." *Monitor on Psychology*, American Psychological Association, May 2016, www.apa.org/monitor/2016/05/numbers#:~:text=The%20number%20of%20Americans%20over,to%2026%20percent%20in%202014.

2. "CDC: 1 in 4 US Adults Live with a Disability." *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 16 Aug. 2018, www.cdc.gov/media/releases/2018/p0816-disability.html.

3. Goldsberry, Gabriel. "VEX Robotics Wiki." *Tank Drive [VEX Robotics Wiki]*, www.vexwiki.org/robot_design/drive_trains/tank_drive#:~:text=two%20%E2%80%9Csides%E2%80%9D.-,Advantages%20to%20this%20drive%20system%20include%3A,which%20wheels%20are%20at%20angles.

4. "Mecanum Wheel." *Wikipedia*, Wikimedia Foundation, 16 Jan. 2021, en.wikipedia.org/wiki/Mecanum_wheel.

5. "World's Largest Selection of Electronic Components Available for Immediate Shipment!®." *DigiKey Electronics - Electronic Components Distributor*, www.digikey.com/.

6. "CLF-1000." *Robot Shop*, 2021, www.robotshop.com/en/lidar.html.