Shop Cleaning Robot Vacuum

Project Closeout Report

Saoud Ashkanani - ashkansa@oregonstate.edu
Hamza Swati - swatih@oregonstate.edu
Derick Rummel - rummeld@oregonstate.edu
Andrew Noah - noahan@oregonstate.edu

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1 Design Impact Statement

1.0 Introduction

The Shop Cleaning Robot Vacuum was a senior capstone project proposed by Project Partner, Donald Heer, for the ECE and CS Senior Design Class of 2021. The project partner owns a woodwork shop in Corvallis, Oregon. The shop has a lot of wood waste and small metal objects, such as nails for example. This waste material requires a lot of human effort to clean and an easier way to solve this problem would be to get a robot vacuum to clean up, while there is work going on and also when there is not. The project partner tried buying multiple commercially available robot vacuums but they were not successful as none of them had enough power to work in a woodwork shop. Therefore, he decided to create this interesting project to find a solution for the issue. This project was taken up by the Senior Design students at Oregon State University. The robot not only requires one Electrical Engineering team for locomotion, but two ECE teams and a Computer Science team as well. The electrical engineering side is divided into a power and propulsion team and an embedded systems team, while the computer science team handles the navigation system of the robot.

The purpose of this assessment is to study the impacts of the robot on areas such as public health, safety, welfare, cultural, social, environmental, economic and any other additional areas.

2.0 Public Health, Safety, and Welfare Impacts

The Roomba, and other robots like it, have improved the quality of life of the handicapped. “In the last decade, care robots (CRs) have been the main topic of several projects and initiatives to improve the quality of life” [x]. These robots perform simple tasks that can be a challenge for the handicapped. An example of this is the Roomba sweeping the floors and a garbage collection system by DustCart[x]. These CRs were to be implemented with an IR receiver and use RC5 protocol, they all could be controlled wirelessly from one spot. This can be done by either setting up a remote control or using a Google Home with a IR transmitter.

Safety is an area that may be affected by the robot in positive ways. The robot will clean the woodwork shop of saw dust and pick up nails, which definitely makes the shop more safe for working there. Nails can pierce through human skin and cause temporary or permanent damage. Then the saw dust in the woodwork shop also has damaging effects on the health of the people working there. According to an article [5], sawdust can cause irreversible damage to a person's lungs by scarring the lung tissue.

Public health may also be positively affected as the issues with working in an unclean woodwork shop may injure or make the people working there sick. The injury or sickness may make the person affected go see a doctor. This causes a load on the health care system that could have been avoided.

Welfare is a segment that is positively and negatively affected by the robot. The robot is an automated device that reduces human effort. Reduction of human effort means taking someone’s work from them. This has a negative impact as there could have been a job created for someone else if the robot was not there. However, it does free up time for the people that are working in the shop, and also leaves more resources in the shop to work on more projects, or just use those resources in an area that may be more important.

3.0 Cultural and Social Impacts

Since the introduction of the Roomba in 2002, it has affected the home dynamic. For an example of this I will look at a exterp from the Service Robots in the Domestic Environment: A Study of the Roomba in the House.

"When the Roomba was introduced to multiple members of a family, a specific set of relations was established that enrolled the entire family in the use of the Roomba, leading to the refiguring of housekeeping practices. In contrast, when the Roomba was introduced to a single family member, the same experience did not unfold."(pg.6)

When the family decided to purchase a Roomba, housekeeping practices changed. Generally speaking, they relied on the robot to clean the floors so they worked on other tasks. This reliability, for some families, eventually turned into an emotional and social connection to the robot.

Day by day there is more and more involvement of robots in our daily lives. They are co inhabiting with humans and therefore do have some cultural impacts. According to Bran Allenby, an engineer and ethicist at Arizona State University, robots are challenging fundamental ethics and cultural ideas of human beings [6]. The shop cleaning robot vacuum will definitely have an effect on the mindset of people that use it. It may make them be more dependent on robots for more work in the future as it makes work easier for them.

There are positive social impacts of this robot, as the people working in the shop do not have to worry about cleaning the shop after they are done, they have more time to spend after they are done. They can use this time to be with family, friends or just to themselves.

4.0 Environmental Impacts

Our product, like many other robovacs, strives to be energy efficient. But in reality, they increase the amount of energy a household uses.

"When compared to manual vacuums, robotic vacuum cleaners use less electricity per unit of time, which explains why robovacs can be defined as "energy-saving" appliances. However, despite the expectation that robotic vacuums would replace manual ones, the authors discovered that owners continued to use traditional vacuums for "proper" cleaning."

Since robovacs are used as supplemental cleaning devices, both devices are used to clean the same area. This overlap causes the overall energy consumption to increase. Depending on what types of energy plants are providing power, more greenhouse gases could be expended. This in turn speeds up global warming.

Saw dust in the air is bad for air pollution, and the robot will minimize in some ways, which is good for the environment. However, the robot has batteries that will become unusable at some point and will be disposed of. If disposed improperly these batteries corrode and leak chemicals that damage the soil and groundwater [7]. The robot is made of plastic and that could take from 20 to 500 years for it to decompose [8].

5.0 Economic Factors

As stated previously, robovacs are a supplemental cleaning device. But despite that, they still see use in commercial and residential environments. This is because they help reduce the time needed for general cleaning. For example an average cost to clean a carpet floor per square foot is $0.25[4].As long as the cost of running the robot vacuum is close to $0.25, time saved is worth. This cost includes upfront cost for the robovac and the power to run the device for a year. Assuming we have a 2,000 sq ft area. The number of time the robovac would need to run is as follows:

$$Runs(upfront) = ((times\ cleaned) * (cost\ per\ sq\ ft) * (Area)) / \ Cost\ of\ robovac$$
$$Runs(upfront) = ((24) * (0.25) * (2000)) / \ \$200 = 60 \text{ times}$$

$$Runs(power) = ((times\ cleaned) * (cost\ per\ sq\ ft) * (Area)) / \ power\ use\ per\ year$$
$$Runs(upfront) = ((24) * (0.25) * (2000)) / \ \$300 = 40\ times$$

The robot also frees up time for the people working in the shop, so it gives them more time for innovation, creativity, working, hence that may have positive impacts economically. That could be for the shop or the society as a whole. The robot however, may be taking away a potential job, that is a negative effect. There is a huge unemployment issue going on in the state of Oregon [9], especially due to the Covid-19 pandemic, this robot may add to that.

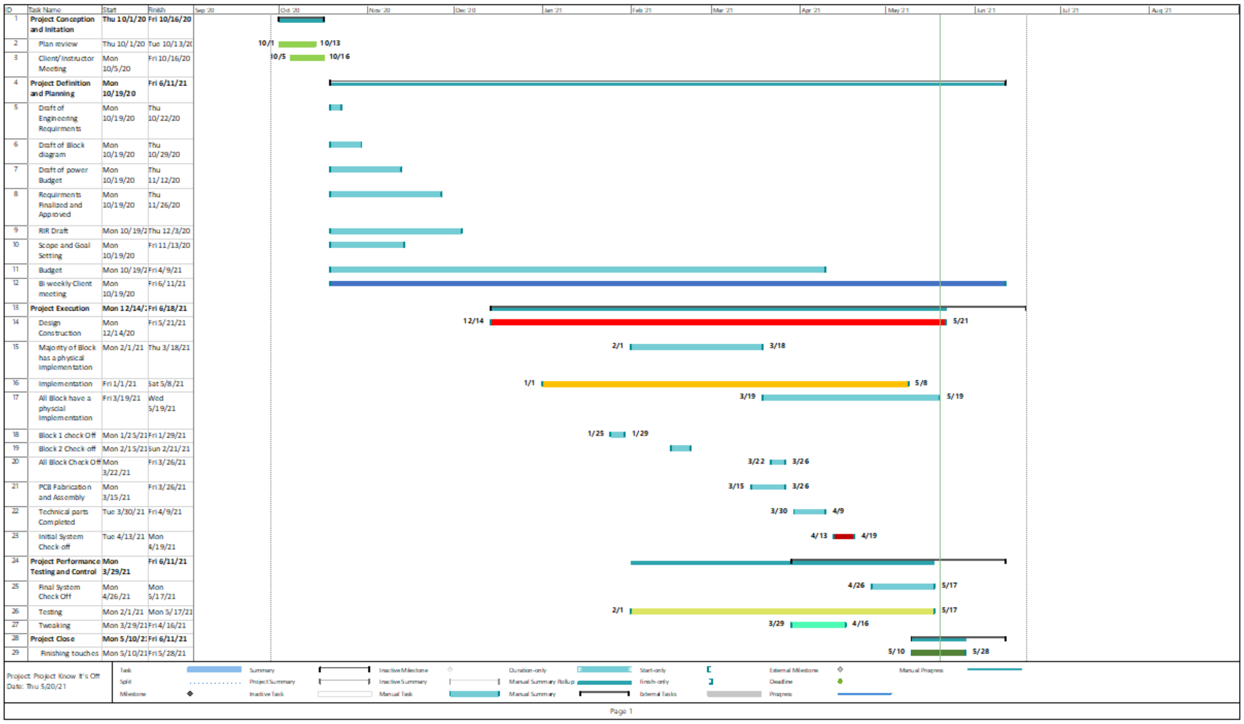
6.0 Additional Impacts

The robot has impacts such as innovation, creativity and learning for the students of Oregon State University. My teammates and I have gained a lot of knowledge working on this project which we may be able to use later in our career. This project also serves as an example for the upcoming students at the university. This is a positive impact and will definitely last for a while.

7.0 Conclusions

The robot has many positive and negative impacts on all of the areas we discussed. There are always pros and cons to all decisions we make as human beings. However, there are some negative impacts that should stop the progress of projects, and fortunately the robot does not have any such adverse effects. The robot will provide safety and more time for innovation, spending with friends and family to the people that work in the shop and those are very positive impacts that far outweigh the negative impacts. The environmental issues of the robot are something that can easily be overcome, if proper measures are taken for the disposal and recycling of the parts.

2 Project Timeline



3 Scope and Engineering Requirements Summary

Since our initial design team for the robot was ten people, we decided to split into sub-teams of three to four people. Those teams are the navigation team, the embedded systems team, and the power and propulsion team. As our name suggests, power and propulsion is responsible for correctly supplying power to the rest of the robot from onboard batteries, and designing the station that the robot will travel to for recharging. We also monitor the batteries so that the robot knows when it needs to travel back to its home station to recharge. On the propulsion side of things we also make sure that the various motors such as the wheels and the vacuum are able to interface smoothly with the onboard microcontroller.

When we were speaking with our project partner we came up with some hard requirements that our system had to have. Our robot needs to be able to find its way back to the charging station and accurately align itself on the charging base so that a proper connection can be made. Our navigation team can handle giving the robot a general idea of where the charging base is, but to ensure that the connection is solid we came up with the idea of using infrared emitting diodes on the charging base that the robot could use to line itself up. By having two emitters mounted on the base and two receivers mounted on the robot we would be able to have the robot line itself up exactly in both directions.

The robot being able to find the charging station is one thing, but for that to be useful the robot needs to know when it's batteries have run dry. For state of charge detection we've decided to go with coulomb counting due to its relatively simple implementation and the accuracy with which it can achieve if the calculations are done correctly. We'll implement the coulomb counting module to monitor the state of the battery's charge and to output that information to the display mounted on the top of the robot.

Our project partner raised the concern that our robot should know when the dust container has filled so that it can know to cease operations. In order to achieve that we will mount several light emitters and receivers within the container. The theory is that the more the container fills up with dust and debris the less light will be received from the emitters signifying the approximate amount the container is filled. Once there is little to no light being received the robot will know that the container is full and will move itself to the charging station and signal to the user to empty it.

Furthermore, there must be multiple levels for the fullness of the dust bag so the robot and user may get aware of upcoming responses beforehand. This trend was followed from the established industrial automation practice providing a high and then high high alarm, one of which provides information and the 2nd one intervenes the control loop giving signal to the actuators. Also, the robot must have state of art kinematics with a smart motor control system knowing the direction, speed and behavior of wheels and prompting in case of any wheel entanglement or mechanical issues arises shutting down the system at the very moment.

4 Risk Register

There are several risks that we might face. Sometimes we are unable to continue development until another subgroup has achieved a higher level of progress, and there might be a delay in getting the parts in time. For example the lithium batteries might take some time to be delivered and due to COVID-19 it might take longer than usual. One huge risk that we might face is that the robot doesn't move, or it might not go straight, or tangle.

To avoid these risks, it might be helpful to create a timeline for each subgroup. Testing the code several times, or making sure that everything is properly connected, and ensuring that a sufficient amount of research has been done, and finally making sure to order the parts before and not leaving it for the last minute.

RISK ID	RISK DESCRIPTION	RISK CATEGORY	CHANCE OF RISK	RISK IMPACT	PERFORMANCE INDICATOR	RESPONSIBLE PARTY	ACTION PLAN
101	Different subgroups will be unable to continue development until another subgroup has achieved a higher level of	Internal	40%	L	Subgroups reach a bottleneck	Potentially anyone	Reduce,shift priorities toward future research or help other groups

	progress						
102	Parts that need to be ordered and shipped could see a delay due to COVID-19	External, shipping	20%	H	Necessary parts do not arrive on time	Non applicable	Reduce / retain: complete testing with available parts if possible otherwise wait for shipping to complete
103	Motor prove unable to propel the robot at the necessary speed, or at all	Internal, Design, Parts acquisition	10%	H	Robot doesn't move fast enough or at all	Power and propulsion member	Avoid, ensure that sufficient research is done into the purchased motors to ensure they are strong enough
104	Power requirements are not met	internal, design, communication	30%	H	Robot movement is sluggish	Power and propulsion member	Avoid, foster communicatio n between subgroup ma to determine total power needs
105	Data protection risk	legal	5%	H	Data protection measures	Potentially anyone	Keep work protected from friends
106	Intellectual property	legal	20%	H	Copywriting and patenting	Potentially anyone	retained

107	Batteries do not allow the robot to operate for the necessary time to clean the entire room	operation	10%	H	Robot needs to charge midway through cleaning	Power and propulsion member	Avoid, perform sufficient research to determine the type and quantity of batteries for the floor space to be covered
108	Communication between team members could be difficult due to some members operating in different time zones	Internal communication	10%	H	Some members left out of the loop	Potentially anyone	Reduce, schedule meetings to accommodate the afflicted party, and keep notes on important meetings
109	Navigation system unable to maneuver through a room	Internal design	20%	H	Robot moves aimlessly , if at all	Navigation team member	Retain, if the system cannot be made to work switch to different method of navigation
110	Failure of embedded systems to successfully communicate navigations information to propulsion	Internal design	10%	H	Robot doesn't move or struggles to navigate	Embedded system member	Avoid, frequent testing and check ins to keep everyone on the same page

111	Damage/Burning of embedded board, motor encoders and other sensitive equipment	Internal design	35%	H	Performance indicator :Unwanted behaviour from the controller or encoders and proving faulty after testing	Power team or embedded team	Keep reserve items which are more prone to minor circuit faults and order immediately so the work may continue without a hitch
112	The response time from nav team is not fast enough to match efficient kinematics from motor control team	Internal design	15%	M	Robot is taking slow decisions for turns and motion	Navigation or embedded team	Keep the code flexible to changes and avoid using polling for sensors prioritizing interrupts

5 Future Recommendations

The ways we could improve the project by increasing dust bag size and also increasing IR sensors thus providing a larger storage and multi level monitoring. Furthermore, we can also improve by providing an android supported mechanism where the user can control the vacuum cleaner robot through the app and can also see the level of dustbag and other robot behaviours.

Also, the charge connectors can be improved by designing some locking mechanism, such as magnets, further improving the connectivity where the robot can easily unlock its connectors by signals from its controller when fully charged.

Another area to improve is the PCB. Currently, There is a lot of unused space on the board. By adding more blocks to the PCB and/or removing unnecessary space the PCB can be refined. Also the current PCB has the Real Time Clock block implemented on the PCB. In its current state, it doesn’t work. This is due to too much current being drawn from the 5V source for the real time clock. This can be remedied by either choosing a different clock or by providing the real time clock with its own 5v power supply.

Along with that, the current implementation of the motor control lacks refinement. It has just enough functionality to complete the necessary task for check off. These would be: forward backward, and turn left and right 90°. This lack of movement decreases the amount of options the robot can go. On top of that, the current implementation barely uses the wheel motor encoders. By fully implementing the encoders, the robot can turn at angles other than 90°, control its speed, and go in a straight line all by counting the number of rotations the wheels have made.

Lastly, our group communication with the CS team for this project was lackluster. The poor communication means that the commands between the power and navigation team are limited. The only defined command communication is for setting the speeds for each wheel. These two commands could perform all movement related tasks, but that would be slow and hard to control. But by adding more commands, the navigation team could more accurately move the robot quicker.

7 References

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