Shop Cleaning Robot Vacuum:

Embedded Team

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Design Impact Statement

The system which the team created is a sub portion of a shop cleaning robot, designed to autonomously navigate it's environment and clean up dust and small debris from the floor. In order to accomplish this task the robot incorporated a variety of sensors to facilitate navigation, including bumpers, cameras, IR sensors, and internal monitoring systems. This array of sensors, as well as the purpose and design process of the robot, present potential impacts to various groups of people.

Potential public health and safety impacts stem mostly from the inclusion of the advanced sensors used by the robot for navigation. The risk is that an outside party could gain access to the robot's sensor readings, thereby spying on the user and their home anonymously or stealing information about the user directly from the robot. An even greater risk is that, as the robot is mobile and autonomous, that third party could actively drive the robot about in order to see whatever they wanted. As noted by the BBC, we as a society have become more comfortable with the presence of cameras, but we are not always aware of who is looking through them [1].

Potential cultural and social impacts of the system are mostly on the positive side. Typically, average citizens need to spend a certain amount of hours each week cleaning their houses, which often includes sweeping the floor. The use of our robotic vacuum has the potential to eliminate the time spent cleaning the floor, which could then allow the user to spend time on other tasks or with more leisure time, thereby reducing stress. Research has shown that the use of one robotic cleaner in the home reduced the time spent cleaning by about one hour [2]. The potential downside to this change could be the loss of the satisfaction some people feel when they clean their home themselves.

Potential environmental impacts are the amount of material and waste which is produced in order to produce the system. Microchips in particular require a large amount of raw materials in addition to harmful chemicals and byproducts which are created. The production of a microchip costs 600 times its own weight in fossil fuels, and many chips produced today require rare metals which are mined at an even greater cost to the environment [3]. The production of microchips is increasing at a steady rate year upon year, and it is the responsibility of our design team to minimize the use of these chips as much as possible for the benefit of the environment and the world in the future.

Potential economic impacts are positive in that the use of the system represents potential savings in not having to hire cleaning staff. Commercial shop cleaners can charge upwards of 75 dollars an hour, a price which would quickly eclipse the cost of our system [4].

The design of our system has the potential to do both good and bad for the end user and the communities surrounding its production. In order to mitigate the potential risks as much as possible, it is important that the software system we design is secure and robust in order to prevent outside parties from gaining control of the robot and using it for bad purposes. Next, be aware of who the end user of our vacuum will be, and do not attempt to force its use on people who do not want it. Then, ensure we are aware of the environmental impact of the components we choose to use in the robot. By being aware of the cost we will not use an excess of parts simply to make our lives easier. Finally, keep the cost of the robot as low as possible, in order to benefit potential future users and the design team itself.

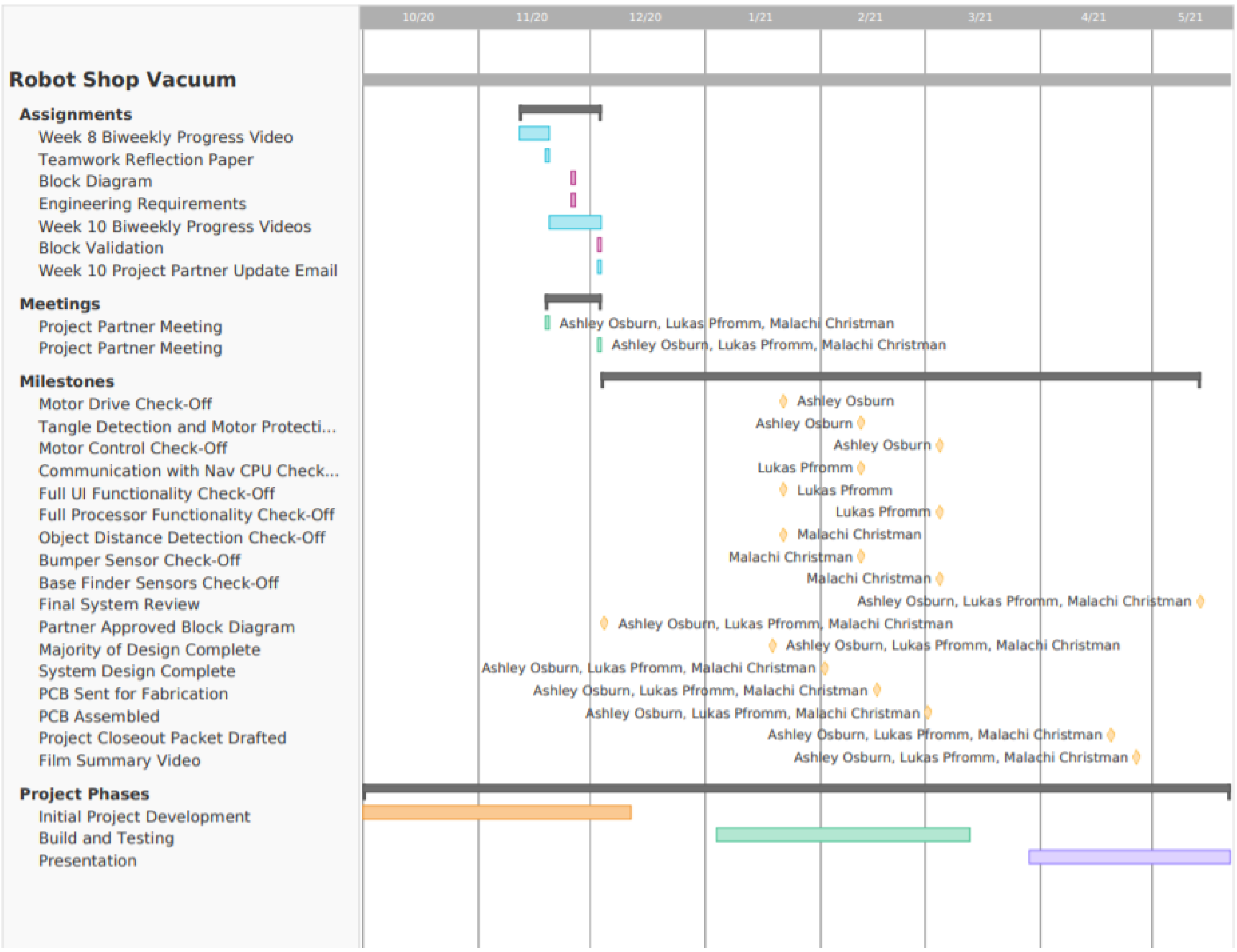
[1] E. Selinger, "The dangers of trusting robots," August 2015. [Online]. Available: https://www.bbc.com/future/article/20150812-how-to-tell-a-good-robot-from-the-bad. [Accessed 4 2021].

[2] S. Gutmann, "The Social Impact of a Systematic Floor Cleaner," ARSO, 2012.

[3] E. D. Williams, "Environmental impacts of microchip manufacture," Thin Solid Films, vol. 461, no. 1, pp. 2-6, 2004.

[4] “Commercial Cleaning Cost 2020: Average Rates & Prices,” Desert Oasis Cleaners, 10-Jan-2020. [Online]. Available: https://desertoasiscleaners.com/commercial-cleaning-cost/#:~:text=The%20average%20cost%20of%20commercial,%2450%20to%20%24100%20per%20hour.

Project Timeline



Scope and Engineering Requirements Summary

Cleaning	The system will sweep debris ahead of the robot smaller than 5 mm in thickness from the floor towards the opening of the vacuum.
Collision Detection	The system will detect if one of the bumper switches is hit. When the bumper is hit with an object, the system will output which side of the bumper is hit: left if the left part of the bumper is hit, right if the right side of the bumper is hit, or center if the center of the bumper is hit..
Communication with CPU	The system will support the status updates listed in the 'Command Interface' Google Doc: https://docs.google.com/document/d/1mbS1jySUtclh21ppn_JF7uFOdZLku_NinsdbgMOD7xY/edit
Data Logging	The system will feature a connector to directly monitor the serial channel between the two processors. Data will be monitored and saved to a file via an external PC.
Detection Of Object	The system will detect solid objects that are no shorter than 6 inches, no thinner than 3 inches, and no further than 30 inches in front of the robot. The system will output the direction and distance of the object.
Navigation to charger	After cleaning, the system will attempt to locate the base station. If the base is in line of sight the system will output the direction of the base. If the base is not in line of sight the system will output an error.

Tangle Detection	If any brush slows down to less than 50% of normal RPM or motor current exceeds 5x nominal current due to external forces, the system will shut down all motors and notify the user of a tangle detected.
Thermal Protection	The system will shut down all brush motors if any motor thermistor temperature exceeds 70C.

Risk Assessment

ID	Description	Category	Probability	Impact	Perf. Indicator	Responsible Parties	Action Plan
R1	A part is delivered late.	Timeline	40%	L	A part is not delivered by the expected date.	Malachi: chrimala@oregonstate.edu	Retain: Focus on other parts of the system while waiting for delivery.
R2	The project runs out of funds.	Cost	5%	H	The budget for the team has nearly been spent.	Ashley: osburna@oregonstate.edu	Reduce: Be conscious of how much money is spent and plan for future expenses.
R3	The client is dissatisfied with the final product.	Technical	10%	H	The client says they do not like the final design.	Lukas: pfromml@oregonstate.edu	Avoid: Give the partner frequent updates to avoid misleading expectations.
R4	Hardware is damaged.	Technical	30%	H	Unexpected operation of the product.	Malachi: chrimala@oregonstate.edu	Reduce: Buy multiple components if possible and make sure to follow datasheet specifications. Implement protection circuits.
R5	There is a conflict between team members.	Personnel	10%	M	Two or more team members have a conflict.	Lukas: pfromml@oregonstate.edu	Transfer: Contact Ombuds if necessary.

The highest rated risk we have is of hardware being damaged. This is likely to occur, especially since the system we are making is essentially a prototype and quite a bit can go wrong during design and testing. The first step we want to take to mitigate this risk is to buy duplicate parts when possible. This will reduce any downtime which could be incurred by waiting for another part to ship and arrive. The next step is to closely follow the guidelines on the datasheets for the parts we purchase, and to integrate protection circuits wherever possible. This will once again decrease the risk of accidentally destroying a part with too much current or using a part incorrectly and causing damage. Lastly we will be cautious when installing or testing components, to avoid physical damage from dropping a sensitive part or while installing it into the system.

The second highest risk in our register is that a part will not arrive on time. This is a risk which has to be taken in any project but we will mitigate it as much as possible with planning and design practice. When ordering a part, we check quoted shipping times to ensure the part should arrive before the date it is needed in the project. We will also try to order parts as early as possible, so if a delay does occur the part can hopefully still arrive before it starts to delay progress on the rest of the system. Lastly, if a part is delayed long enough to where it affects the development cycle, whoever is waiting on that part will shift their focus to another system or help one of the other team members, so we do not have idle team members waiting on a single part.

The third highest risk is that the project partner is dissatisfied with the final system which we produce. To avoid this risk we will stay in constant contact with the project partner to ensure they are aware of where we are at in the development process, and to ensure that all the specifications they had in mind are met. That way, there will be no miscommunication towards the end of the project with the partner expecting something different than what the team is ready to deliver.

Future Recommendations

1. **Redevelop the communication software and format:** Currently the system communicates only with the high-level CPU of the Navigation team using a table format of bytes. This only allows for communication using that data type and does not allow for extremely rapid communication in an emergency.
   Recommendation: Instead of a standard based purely on bytes, allow the Nav processor to ask for data from a specific sensor and utilize a more appropriate data type which maintains accuracy. Also, the inclusion of at least one interrupt pin directly to the Nav board to allow for emergency stops.

2. **Have a pre-developed plan for PCB assembly and test:** In our project, we assumed PCb assembly and testing would be possible to accomplish for a single member of our team, which was unfortunately necessary. This resulted in assembly taking longer than necessary if more people had been involved, and unforeseen issues occurring at the end of the project which hampered the effort to complete it.
   Recommendation: Set times and have a plan for who will work on the PCB, and do not discount the amount of work required to assemble a PCB with a large number of components. Also let team members test the portion of the board or project they are responsible for designing.

3. **Expand sensor coverage of the robot:** Currently, the robot has essentially all of its navigation sensors pointing directly forward, which introduces risk if the robot were to try to back up or navigate in a tight space. Additionally, the robot has no protection against driving off a ledge or stair.
   Recommendation: Add in a downwards facing TOF sensor which will allow the robot to see the distance to the ground. This will let the robot know if it is about to drive off a cliff. Also add in safety sensors like bumpers to the back of the robot.

4. **Schedule times for working on non-hardware components:** Due to the nature of working remotely, our team was especially hard hit by the issue of not spending an adequate amount of time working together on code or design files. This resulted in code oftentimes not using similar interfaces, and final code integration being much more difficult than necessary.
   Recommendation: Schedule times to work on software and documentation in addition to just hardware and assembly. This will allow quick questions to be asked which are vitally important to the team remaining on the same page, and also helps build comradery.

5. **Be aware of component packages and your soldering ability:** Certain components, such as resistors, capacitors, and microchips often have extremely small and delicate contact patches and sometimes require specific methods to be soldered correctly. The team believes on one chip with one hundred pins a soldering error caused a critical bug later in the testing process.

Recommendation: Pay close attention to the components you select and be sure you will be able to hand solder them with enough certainty that they will work. Otherwise, ask for help from someone more experienced or use a part with larger contact patches.

6. **Do work on the project early and often:** Our team, perhaps as a result of working remotely, would often do most of the work close to the deadline, when critical defects in the system were much more damaging than earlier on.
   Recommendation: By doing work on the project more granularly and from an earlier start, it becomes more obvious earlier in the process when an issue is present which could damage your progress. This thereby reduces the chance of a catastrophic error close to a project deadline.

7. **Develop code in coordination with other teams:** Our coding process for the final system was challenging due to our team members being split and the time constraint we were under to hit the final checkoff deadline. This also meant that between the code of the three teams, there was no common layout in the structure, variable names, or layout.
   Recommendation: Agree with the other sub teams on general rules and conventions to follow when writing code. This will result in code which can be more easily read by any member of the team, streamlining the final integration process.

8. **Improve capture of sensor data with external processors:** In our system, one single processor is responsible for completing the code of three separate team members. This can sometimes lead to the processor developing a backlog of data and potentially missing information in the serial buffer.
   Recommendation: Use some type of capture device, perhaps a peripheral processor, which can capture and store data until the main processor requests it. This allows the serial ports of the main processor to remain open, and helps to mitigate the chance of data being lost.