ELEC 390: Main Project

Project Title: Embedded System Solution to Snow Removal with Network Capability

Team 26
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Abstract

Shovelling driveways in harsh winter conditions is a very strenuous task for families and the elderly. This can lead to short and long-term injury. This project is focused on a network-based embedded system application that can plow driveways autonomously. This autonomous application will eliminate the risk of injury to shovelling snow. The embedded system used will be an FPGA chip and the language for the software being used will be C. This application will be on a medium size rover of about three feet in height and about three feet in width. This application will use sensors to determine where to navigate on the driveway and where to plow the snow. The impact of this application will help prevent injury and help families save time in the morning to focus on more important tasks than shovelling. The steps our team will use to achieve this will be divided into three major sections. The first section will consist of getting familiar with the FPGA chip being used and how we want to implement that on the application. The second section will consist of assembling the vehicle and the connection to the FPGA chip. Lastly, the third section will consist of implementing sensors to the vehicle to allow autonomous movement.

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Problem Description

As the technologies in automation and embedded systems evolve, new solutions have the potential to solve traditional problems that people would otherwise suffer from. A very simple, yet dangerous hazard to living in cold environments is the safe removal of snow from driveways and sidewalks. Conventional technologies include manually operated snow plows or heated driveway. Gas and electric snow blowers still require a labour-intensive operation and heated surfaces cost upwards of $15,000 [1] to implement effectively ruling out both options. Therefore, the need exists for a cost-effective and automated solution to snow removal.

Although on the surface, snow removal can be a simple task, there are hidden underlying hazards that have been shown to cause serious health problems and possibly death. The most obvious at-risk individuals prone to injury would be the elderly population. The weakened bodies of senior citizens are more susceptible to bone damage and may already have pre-existing conditions such as weak lungs that would compound the difficulty of snow removal.

The general population is also at great risk from suffering heart attacks related to physical exertion during snow removal to the point that hospitals in colder regions prepare especially for an influx of such cases. As the overall population exercises less and unhealthy eating habits increase, the probability of heart-related issues increases. After not exercising for several months in the summer, the first shovelling of large amounts of snow puts a great amount of stress on the heart. Furthermore, the cold weather itself is a factor in increasing the likelihood of heart attacks as it interrupts blood flow, increases blood pressure which results in the creation of blood clots [2].

Research conducted by US Nationwide Children's Hospital found that in the USA alone, 1,647 deaths were recorded between 1990 and 2006 as a result of cardiac-related injuries from shovelling snow [3]. The same study also concluded that when healthy young men shovel snow, their heart rate and blood pressure increased more than exercising on a treadmill. It went to highlight ineffective snow shovelling often occurs in the early morning right when circadian fluctuations make the body more vulnerable to heart complications.

The direction of demographics can be concluded to heading in directions where more injuries will result from snow shovelling. The largest portion of the population will soon be baby boomers reaching their senior years and the general trend among citizens is to exercise less and an increase in obesity rates. Therefore, there is a clear need for a solution that enables the automation of private property snow clearing in a cost-effective manner.

Impact

The primary impact of the product will be a large reduction in injury to consumers. Approximately 195,100 individuals were injured in snow-shovelling related incidents between 1990 and 2006, averaging 11,500 individuals annually. The injuries range from soft-tissue to cardiac-related issues. The three typical methods of injury from snow shovelling were over-exertion, slips and falls, and being struck by a snow shovel. Of the 195,100 individuals injured, 95.6% of incidents occurred in and around the home, making it the primary location for a solution to be designed. Older adults aged 55 and above accounted for 21.8% of injuries, making this demographic an ideal target market. All injuries and deaths related to snow shovelling are completely preventable by having an embedded system complete the task for the consumer [4].

A cultural impact would also be felt throughout the Canadian landscape. Shovelling the driveway has become a staple of Canadian culture, and the complete automation of the process would be alien for many Canadians. The product would have to be sold as means to save time and prevent injury instead of touching on the loss of a Canadian pastime. Many families use time shovelling to bring them closer and develop a stronger family bond. Although, it would be expected that families that currently hold this mentality would not purchase the product and would continue personally shovelling the driveway.

The ethical impact of the product would be the lack of requirement for exercise and outdoor time during the winter. The extent to which this affects a population could be seen through a drop in physical capabilities as many Canadians use the act of regularly plowing their driveway as a workout. As well, this would impact the human interaction of some residents in their area. This could also fuel an ideology that technology could drive us apart as people. Without the requirement for people to be on their driveway shovelling, Canadians would be less sociable during the winter months.

On top of the promise of the product to save consumers from injury, it also offers valuable time-saving to people of all ages. To calculate the TAM, research is done into the target market as well as its purchasing power to create a bottom-up approach. As of September 27th, 2017, the population of Canada is 36.7 million with persons aged 55+ comprising over 30% of the population. StatCan also provides information on median net worth of people of different age groups. StatCan reports that the median net worth of the major income recipient in a family is $669,500. This provides ample purchasing power with expendable income to provent injury. Using a conservative estimate of 2%, if 2% of the Canadian population aged 55+ purchases an automated snow plow, this means that 220,200 Canadians will purchase the product. With a full-sized plow priced at approximately $1000, the revenue for the product would be over $220 million. These projections are based on the soon-to-be/current elderly population in Canada and do not account for a younger generation of individuals who choose to purchase the product to save time [5]. It would be increasingly difficult to estimate the size of a younger target market who are using the plow to save time, and have enough expendable income to do so.

Solution

The characteristics that make up the overall problem can be described as the health hazards that occur as a result of snow shovelling and the unreasonable costs that need to be covered to attain alternative less labour-intensive methods of snow clearing such as expensively heated driveways. If the human interaction can be reduced dramatically within a range of cost that is similar to buying a household appliance, the solution can be deemed a success.

The current solutions available to solve the problem can be categorized in two disjoint parties including where human interaction is completely removed at a high monetary and environmental cost and the alternative being a solution that greatly reduces human effort due to snow-blowing technology but still requires physical exertion and overhead costs to operate. Heated driveways are a solution that utilizes electric coils or water pipes carrying hot water under the driveway to effectively keep snow from building up on the surface. The heated driveway is unreasonable due to the astronomical utility costs that are incurred from using the system. Furthermore, the thousands of dollars needed to convert traditional driveways make this solution economically unfeasible for the general population [6].The energy required to power this system will be drawn power plants that will produce more carbon emissions for a system that uses energy very inefficiently. The more affordable solutions on the market include snow blowers that use gasoline or electric batteries to power motors that clear driveways. This solution can also be disregarded because it requires continuous human operation creating the same risks as snow shovelling would. In fact, at least one fatality can be attributed to exertion using snow blowers in Buffalo, USA [3].

The lessons learned from current solutions will be taken into account to implement the proposed solution. The primary goal to achieve will be the full removal of human-labour in snow clearing. The solution will be a vehicle capable of movement and navigation without putting human lives at risk of harm. The onboard sensors on the vehicle will communicate with the processor and provide directions for the vehicle to effectively plow snow from the driveway before it piles up into large quantities. The secondary objective of the solution will be to avoid crippling costs that make the product out of reach for the general population. To facilitate this, the vehicle will be designed to be small in size while still being effective at its task. Its small size will require a much smaller power plant in contrast to traditional snow blowers that use loud gasoline engines to blow snow large distances.

Component Analysis and Design

Features

The final design of the plow can be broken down into multiple features as displayed below in the feature table. Features are discussed based on the benefit to the end products and users as well as how challenging the feature would be to implement. The features are broken down into 4 categories that define how the feature fits into the final product. These categories are computer user interface (UI), network and data transfer, embedded software and hardware.

Computer UI encompasses all features that a user will be able to access on a computer that is remotely connected to the plow. This includes a start/stop button that can be used to remotely begin or end the plows operation and a route tracker that displays the path followed by the plow while clearing the driveway.

The network and data transfer section involve operations that communicate information between the computer UI and the plow. This includes one-way transmission from the computer to the drone and two-way communication with transmissions from both the computer and the plow.

The third category is embedded software, this is any features that will be controlled by software on the plow's FPGA. Features in this category include drive and turn, autonomous object detection and avoidance, route tracking, driveway mapping and route planning, and "Home Base" tracking. Drive and turn is the ability for the plow to drive in a straight line and turn through any number of degrees. Autonomous object detection and avoidance involves interpreting data from multiple sensors and making decisions as to were to drive to avoid objects. Route tracking comprises of recording the path taken by the plow as and interpreting this as a route. Driveway mapping and route planning take past routes travelled by the plow and uses it to estimate the size and shape of the driveway it is plowing, from this estimation the most efficient plowing route is calculated. "Home Base" tracking means keeping track of a start location "Home Base" and determining how to drive back there.

The final category, hardware, includes and features that will be implemented physical components. The includes drive and turn, physical area detection, physical and virtual area detection, rechargeable battery and charging station. The drive and turn for this section are different from the previous one in that it is the actual implementation of the motors, not the software controlling it. Physical area detection involves using distance and collision sensors to detect objects and guide the plow. Physical and virtual area detection is an extension of physical area detection that involves adding detection of IR beams that signify boundaries not blocked by physical objects. The next feature involves fitting the plow with a rechargeable battery to power all the components. The final feature is a charging station for the plow, this would be a station the plow could drive into and start charging right away.

Feature Table

Feature Category	Feature	Benefit	Effort
Computer UI	Start Stop Button	- Easy remote control of the robot - Important for user control - High	- Simple UI interaction - Relies on networking layer - Low
	Route Display	- Enhanced user experience - More detailed information - Low	- Complex data interpretation and display - Heavy reliance on networking layer - High

Network and Data Transfer	One Way Communication	- Allows start and stop signal from computer - High	- Sending and receiving data - Low
	Two Way communication	- Enables the computer UI route display - Low	- Both sides must send and receive - Larger and more complex data - Medium
Embedded Software	Drive and Turn	- Basic operation of robot - Necessary for other functionality - High	- Generating equal motor signal for straight driving - Calibrating signal for turning - Low
	Autonomous object detection and avoidance	- Allows for robot to navigate driveway without user input - Prevent property damage and robot getting stuck - High	- Requires many inputs and outputs to function together - Interpretation of obstacles and avoidance decision - High
	Route Tracking	- Enables displacing of route - Aids driveway mapping and route improvement - Medium	- Requires storing route and interpretation on distance travelled - Medium
	Driveway mapping and route planning	- Allows improved performance of plowing - Low	- Increased software development - Distance tracking, measurement and interpretation - High
	“Home Base” Tracking	- Allows robot to return “Home” after plowing - Keeps robot out of the way after plowing is complete - Low	- Additional tracking and computation -high
Hardware	Drive and Turn	-Motors and motor controllers to provide basic driving -High	-Setting up motors to function properly and evenly between both sides -Low

	Physical area detection	- Necessary to detect and avoid collisions - Required for navigation of enclosed area - High	- Distance and collision sensors - Low
	Physical and virtual area detection	- Required for navigation of areas that are not fully enclosed - Medium	- External Device creating invisible boundary (IR Beam) - Detection of set boundary (IR Beam) -Medium
	Rechargeable Battery	- Makes repeat use easier for users (does not have to change the battery) - Less expensive in the long run -High	- Higher initial cost - Design must incorporate access to charging port -Low
	Charging Station	- Allows repeat plows without user interaction - Makes for more autonomous robot - Out of the way place for robot to stay when not plowing - Low	- Must design charging port that can easily be connected by robot driving to it - Relies on tracking of “Home Base” - High

Components and Dependencies

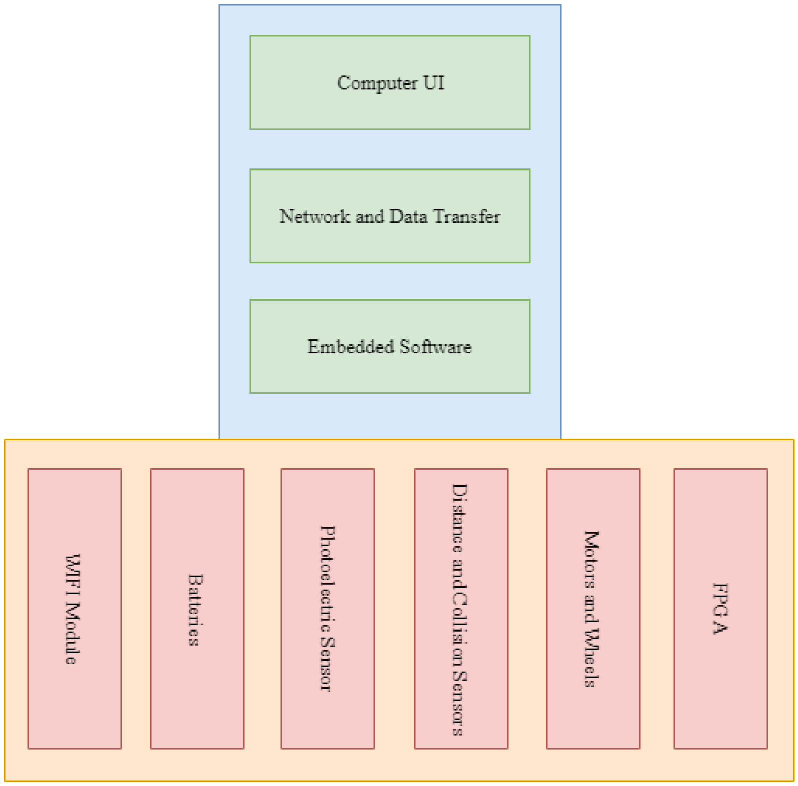

Figure 1: Block diagram detailing the software and hardware components

Software

Computer UI

This will be the only aspect of our solution that the user will interact with, it includes buttons to start and stop the plow and well and display the routes taken by the plow. Inputs to the UI form the user include clicking on the start and stop button. Outputs from the UI will to the user comprise success and failure messages on starting and stopping the plow and route information. One other none UI output is the start/stop signals sent to the plow.

The application will be built using Java or .NET framework depending on which will the development easier. This decision will be made when development starts. If Java is chosen development will use JavaFX and well as scene builder to develop the basic UI. To improve the user experience and create a better-looking UI, libraries such as JFoenix can be used. If the .NET framework is chosen UI development will be done with Visual Studio using WinForms.

The computer application depends on the networking and data transfer to the plow for its functionality. The start/stop button relies on a signal sent from the computer being received and interpreted by the plow. The route display relies on the plow being able to track its route and send this data to the application.

For the computer application, we decided to leave it on the simpler side only adding two simple functionalities. This was done because we want the focus the majority of our effort on the development to be on the plow and not get caught up making a complex application.

Network and Data Transfer

This is a two-part software with programs on both the plow itself and the computer application. These programs will be responsible for preparing the data to be sent, sending the data to the other side and receiving data from the other side. The computer will send start and stop signals that will be received by the plow. The plow will send route data to be received by the computer application.

These programs rely on a few components on both sides. On the computer application side, it relies on the application to initiate start and stop signals and the computers network hardware and drivers to deal with the transmission itself. On the plow side, it relies on the embedded software to provide the data to be transferred and the WIFI module to handle data transfer.

This design was developed out of the necessity to have information transfer between the plow and the application.

Embedded Software

This is the software running on the plow’s FPGA controlling all its actions. The software will most likely be developed using C, but this will depend on the chosen FPGA. The program will wait for a start signal an then will begin driving the plow while looking for and reacting to obstacles. This will continue until a stop signal is received, the battery is low, or the driveway is plowed.

This software relies firstly on the FPGA to run the program and generate and receive the required signals. For all the controls to function properly this software relies on all plows hardware to create the proper signals and respond is the correct way.

Hardware

FPGA

This is the central control module for the drone, it will run the embedded software and control all the remaining hardware. Its function relies on power from the batteries and the embedded software for control.

Motors

Two motors will drive the plow with one powered wheel on either side of the plow. These will enable the driving and turning of the plow. It relies on signals from the FPGA to function and power from the batteries.

To keep the design similar and leave less room for error we decided to have two powered wheels and two unpowered wheels. In addition, all turning will be done by increasing and decreasing the speed of the powered wheels. This removes the need for additional hardware such as servos to steep the plow.

Physical object detection

Both IR distance sensors and physical touch collision sensors will be used to detect walls and any other objects that may get in the way of the plow. These sensors will relay information to the FPGA which will interpret these to decide if there is an object and the batteries for power.

A combination of both distance and collisions sensors was chosen to add redundancy to the system. The distance sensors will be the primary means of object detection but if there is an object that they miss the collision sensors are there as a backup detection method.

Virtual object detection

Not all sides of the driveway are obstructed, meaning that they will not trigger the distance or collision sensors. As a solution, IR beams will be arranged to represent these sides. A module will shine an IR across this barrier an IR receiver will be positioned on the plow so when it drives through this beam it will detect it and know that this is a “wall”. This relies on the IR module shinning the beam, the receiver on the drone and the FPGA. The IR module will have its own power source and sensor will be power by the plows batteries.

Rechargeable battery

The plow will be powered by a rechargeable battery. This will be mounted on the plow and used by other hardware for power.

Rechargeable batteries were chosen over replaceable ones to cut long-term costs and removing the need to have the batteries extremely accessible and easy to change. This will help in simplifying the design.

WIFI module

This hardware for connecting the plow wirelessly to using WIFI to the computer application. Depending on the FPGA selected it will either include an ethernet port or a network card will have to be added on. A WIFI module will be connected to the ethernet port and used for the wireless communication. This depends on the FPGA and the embedded software as well as the computer application to provide and receive the data transmitted.

Risk Analysis

Property Damage

The vehicle could damage the owner’s property while shovelling the snow. The likelihood of this risk is medium because the vehicle may drift off course and damage a piece of the house (i.e. garage, porch), vehicles, or some of the surrounding land of the property. Although the vehicle will not be strong enough to cause heavy damage. The impact of this risk is high as it will result in a cost to fix the damage done to the property. This cost could be very large as the damage from and to the vehicle will need to be repaired.

Obstruction of the driveway

The vehicle is at risk of having the battery die during the plow session or having a vehicle try to come in while it is plowing. The likelihood of the vehicle obstructing the driveway is low. The vehicle will most likely be charging before it is used so will not run out of battery during its use, as well as any visitor coming into the area during the session is low. The impact of this risk is low as it will result in either damage to the vehicle if it runs out of battery and is left out during the cold. Also, it may be damaged by a vehicle trying to enter the area without seeing it because it ran out of battery and is covered in snow.

Injure a person

The vehicle could come in contact with an individual and continue to plow resulting in an injury. The likelihood of this occurring is low, as the plow is programmed stop when it approaches someone, and an individual is easily able to get out of the way of the plow. The impact of this is high as it can result in an injury to a person and the plow itself. This then has a probability to lead to other impacts (i.e. cost, lawsuit).

	Likelihood			
Impact		Low	Medium	High
	Low	Obstruction of the driveway		
	Medium			
	High	Injure a person	Property Damage	

Budget

All the prices listed are estimates and may change as the project develops. The products selected are meant to represent products similar but not necessarily to the exact product we will use.

Item	Cost per Unit	Units	Total
FPGA	~$100 [7]	1	$100
Motor and wheel kit	$160 [8]	1	$16
Distance Sensor	$3 [9]	2	$6
Collision Sensors	$13 [10]	1	$13
Photoelectric Beam Emitter and Receiver	$34 [11]	1	$34
Rechargeable battery	$40 [12]	1	$40
Chassis	$5 [12]	1	$5
WIFI Module	$4 [13]	1	$4
Total without tax			$342
Tax			$44.46
Total with tax			$386.46

Development Plan

In order to execute the implementation of the proposed solution, the team will use a selection of software tools that specialize in project management for agile teams as well as communication aids that ensure there is a strong line of communication between team members.

Trello project-management software will be utilized to track the progress of various milestones for the duration of the project. Keeping in mind the end date of project being final presentation in mid-March 2019, the team will allocate time efficiently to tasks in order of difficulty. The timeline beginning from May 2018 will divide the project into a series of sprints that will each produce an end product that satisfies the requirement of the sprint. Each sprint can be complemented with tasks assigned to specific group members. Sprints will be classified with colour coded levels of difficulty to help allocate a reasonable amount of time and resources to help complete them. Red being the most serious take up to 1.5 months, followed by yellow being a medium level difficulty of 3-4 weeks and green being the easiest being classified as 1-2 weeks.

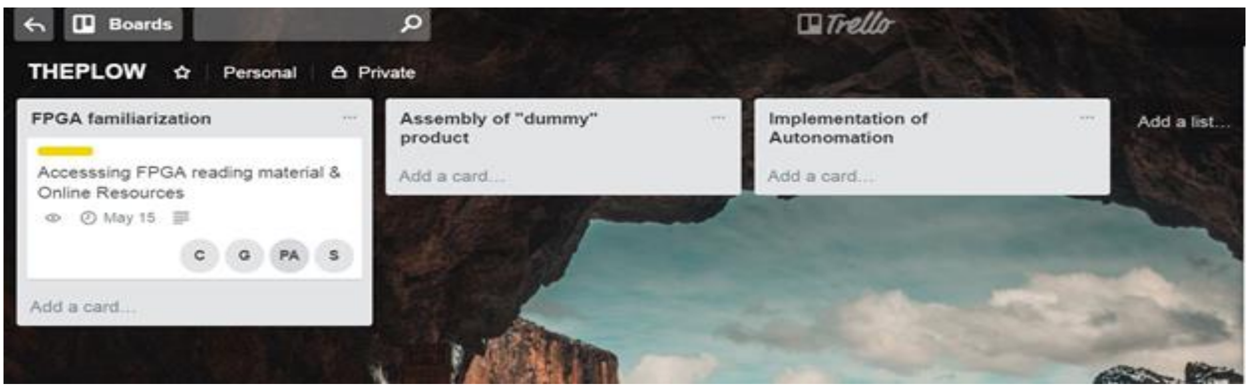

Figure 2: The storyboard of Trello Software showing 3 distinct High Level milestones beginning to be populated with low-level colour coded milestones

The popular collaboration software Slack will also be incorporated into the development plan. It will be used by team members as a platform for discussion and decision making. The flexibility of Slack allows Trello software to be blended into Slack allowing the team to be more effective. The inter-connectivity of these software platforms will allow for the most effective sprints and make sure the project is kept on track.

The disjoint high-level milestones of the project can be described in 3 major phases each composing of just over three months for each phase. The introductory phase will be based around increasing familiarity with the FPGA selected. Since the device selected will act as the processor for the product, it is critical for the team to be comfortable programming and executing a series of instructions that can be translated into actions in the final product. The next major theme of the project is to assemble the physical product and its various components. The body of the vehicle, the battery pack that forms its power plant, the snow clearing attachment, and the various servo motors combined with the wheels of the product make up the components that require assembly and successful operation of "dumb" commands. User controlled movement in 2-D space will be ultimate goal for phase 2. As the project comes to its presentation date, the last phase will focus on implementing the autonomous aspects of the vehicles. Various sensors will be obtained and implemented to allow the product to operate with no human interaction.

The Gantt chart software utilized will be Elegantt since it offers integrated service with Trello and by extension Slack. The team believes integrating the tree platforms will increase the effectiveness of the project management tools.

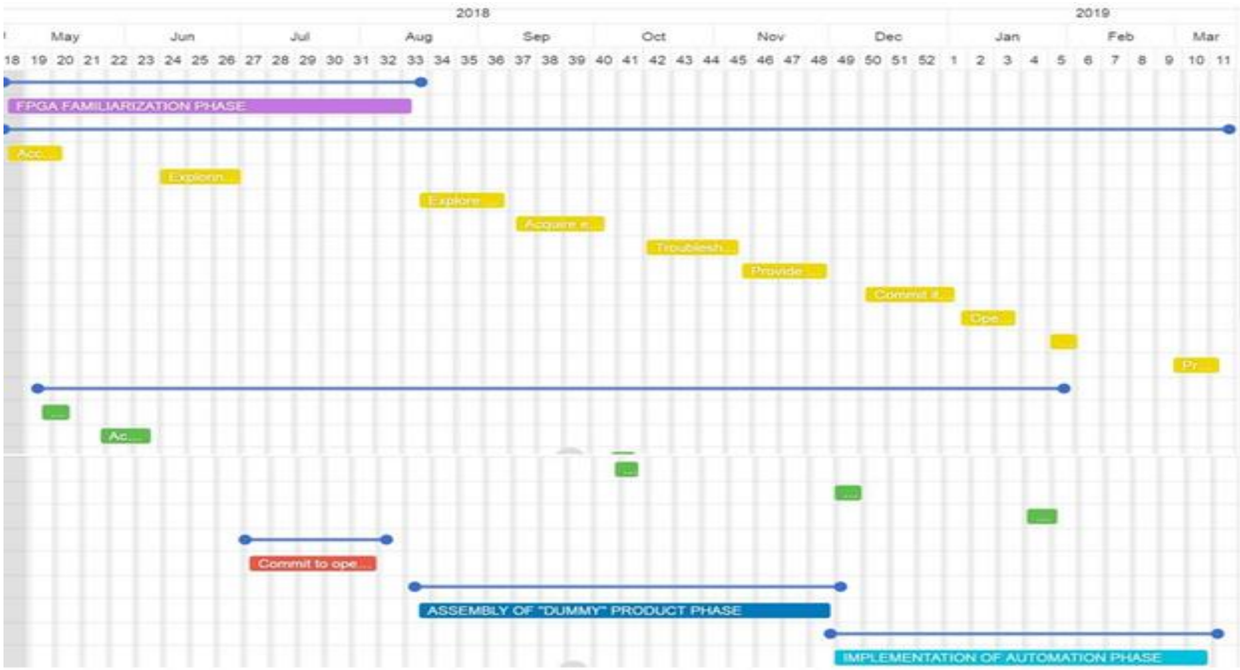

Figure 3: The Gantt Chart model created the Elegantt extension for Trello management software

Gantt Chart Legend:

Phase Sprint Descriptions		
FPGA familiarization	Assembly of "dummy" product	Implementation of Automation
• Final Discussion on complementary networking options for FPGA • Acquiring the selected FPGA chip from advising professor or procurement	• Assemble all collected pieces together	• Test ability of vehicle to handle harder tasks/challenges. Test endurance of battery • Evaluate performance of prototype vehicle
• Accessing FPGA reading material &	• Explore procurement options for	• Commit iterations to software elements of project through feedback from physical tests of vehicles

Online Resources • Exploring Rudimentary Programming of FPGA Boad	products structural components • Acquire electronic components of product that fit well with structural pieces • Provide commands to the product and test effectiveness of moving components	• Operate tests of the vehicle in simulated environment • Present results to public and judging panel
• Commit to operations of an intermediate/advanced level on the gate array	• Troubleshoot errors as a result of product assembly.	• Attempt to operate vehicle prototype in the field

Test Plan

When planning testing for the plow, it is important to separate tests into 4 major areas of testing: component, integration, full system, and field. The component testing plan is detailed in the table below.

Test Item	Intention	Test Method	Inputs	Outputs	Meaning of Outputs
Wheels	To test the average lifetime of a pair of wheels	HALT Test (Highly Accelerated Life Test)	Different wheel speeds	Wear on wheels	The outputs inform on the lifetime ability of wheels
Motors	To test the optimal working conditions for the motors as well as high/low boundaries of operation	-HALT Test -MTBF (Mean time between failure) calculation	-Long-running stress tests that run the motors for a long time -Pushing as much voltage into the motors before failure	-Amount of time before motor reaches a point of failure -Maximum voltage that can be applied to motor before failure	The outputs inform on the functional ability of the motors, as well as their operational levels

Networking Capability	To ensure the networking capabilities can communicate without interruption	Send information	Send information with -increased distance -obstacles interfering	Varying level of information received with varying levels of accuracy	The outputs inform on the ability for the network to communicate over distance as well as through obstacles
Snow Plow Blade	To find the limit for weight the snow plow blade can push	-HALT Test -Baseline Test	Blade tested with -snow covering entire blade -snow covering one half of blade	Blade breaks in certain areas, and under a certain amount of pressure from snow	The breaking point of the blade described how much snow the blade can push before it will break, with a distributed load, as well as a concentrated load
Sensors	To ensure the functionality of sensors	-Baseline Test	IR sensor, distance sensor, touch sensor tested for routine operation	Sensors record their interaction with being pushed, sensing an IR beam, and reading distances	The output of the test is determined by the functionality of the sensor components.

The integration testing plan is detailed in the table below.

Test Items	**Intention**	**Test Method**	**Inputs**	**Outputs**	**Output Meaning**
Motors and Wheels	To ensure that wheels can generate enough torque to push ample snow, as well as drive straight forward under different conditions	-Baseline test -Consistent Load test	-Motors are given the same voltage -Plow pushes an increasing amount of snow forward	-Plow either moves straight or does not -At a certain point, motors are unable to generate enough torque -Car's movement becomes skewed because of uneven snow on plow	-If the car does not move straight forward, then motors should apply different voltage, or plow must be adjusted -Ensure car never attempts to push more snow than it is able

Boundary Sensors and Wheels	To ensure that when the plow breaks the boundary of the course, it can correct itself and stay inside of boundary	Repeated Course Testing	The plow is placed in the course repeatedly at different positions and angles	The plow will attempt to adjust itself when encountering the boundary	The plow will understandably have difficulties when coming into contact with the boundary at varying angles, and these tests cases help to determine how to properly deal with these cases
Networking and Embedded System	To ensure that the plow is accurately tracing its route or is accurately following a route	Repeated Course Testing	-The plow is placed in the course repeatedly at different positions and angles -The plow is given a route to follow	-The plow will accurately or inaccurately trace its route -The plow will accurately or inaccurately follow a route	The output of this test will help to determine whether communications issues are still present between the plow and other hardware

For the full system testing, the plow will be used on a basic test course repeatedly with slightly different starting parameters. These repeated tests will provide important insights into the basic operation of the system. Small inconsistencies and inefficiencies will be targeted and fixed between tests. During this testing phase, the plow will need to interact with the course environment in as many ways as possible to find as many test cases as possible, and fix accordingly.

The field testing plan is detailed in the table below.

Test Items	Intention	Test Method	Inputs	Outputs	Output Meaning
Courses of different shapes	To find which courses the plow operates well on and which it does not	Create new courses with different realistic driveways shapes and repeatedly test the plow	The plow is placed in the course repeatedly at different positions and angles	The plow can complete its task at varying levels of success	Adjust the operation of the plow to ensure that it will work for as many courses as possible
Varying levels of snow	To ensure that the plow can operate in high-snow scenarios as	Fill the test course with varying levels of snow (or	The plow is placed in the course repeatedly at different	The plow can complete its task at varying levels of success	The outputs inform on how the plow will perform under different snow-

	well as low-snow scenarios	other simulated material)	positions and angles		related circumstances, and how to improve
Varying levels of battery	To test the performance of the plow at varying levels of battery	Course test	Place the plow into the course with varying levels of battery	The plow can complete its task at varying levels of success	The ability of the plow at different battery levels
IR emitters covered by snow	To test the plow's ability to detect the boundary of the area given that the IR emitters are covered in snow	Course test	The plow is placed in the course repeatedly at different positions and angles	The plow is able/unable to determine the boundary when emitters covered in snow	This will determine whether uncovering the IR emitters is an important piece of the operation of the plow

Team

Paritosh Arya

I am proficient in C, java, and most popular languages. I have a strong understanding of FPGA chips from my work in 271,274, 371 and 374. I have experience working in data processing and analyzation.

Connor Macdonald

I have experience a variety of languages such as C/C++, Java, HTML and JavaScript. I have experience in web development and building GUI's. Additionally, through my use of Arduino's and Altera Cyclone FPGA's I have gained experience building embedded solutions. I value constantly learning and always try to bring a curious mindset.

Garrett Richardson

I am proficient in C, java, and other languages, I have a strong understanding of FPGA chips from my work in 271,274, and 371.

Stephen Boyd

I have experience coding in object-oriented languages such as: Python, Java, C, and C++. I also have experience creating Arduino projects.

Report Contributions

Team Member	Section of Report Completed
All	**Table of Contents, Team, Deliverables,**
Paritosh Arya	**Problem Description, Solution, Development Plan**
Connor Macdonald	**Components and Design, Budget,**
Garrett Richardson	**Abstract, Risk Analysis, Project Management Software, Beyond ELEC390/49X**
Stephen Boyd	**Impact, Test Plan, and Grammar**

Project Management Software

The software the team will use to manage and communicate for the main project will be Slack and SharePoint for documents (brainstorming, write up, reports). The Slack will be organized in different channels including but not limited to: general, operations, business, reports, and miscellaneous. These channels will allow ease of communication between our team and will help workflow amongst the team members. This can lead to the members being able to see what others are working on for their sections and will help members crossover work to anyone when they need help.

The team will also be using Trello software that was independently found through research. This will be mostly used for the development of our project. It will help for hardware design, algorithm development, and software development. The Gantt chart will be used from an extension of Trello, Elegantt to allow the team to be aware of development, testing, and report deadlines.

With the management software were using for our project with slack, SharePoint and Trello, our team will be organized and transparent with all work needed to be done.

Deliverables

The final deliverable at the end of ELEC49X is a small-scale autonomous plow. The plow will be able to use a network to trace its path through a course onto a computer, will be able to stay within a boundary using photoelectric receivers, and will be able to avoid objects using distance and collision sensors. This final plow will be a proof of concept that a larger scale product could be developed for larger driveways, or roadways.

Another deliverable will also be an algorithm that will find an optimal path to plow a driveway. This will be refined over the course of the project and will hopefully be improved with each course the plow encounters. Proof of the development of the algorithm could be seen through the continuous tracing of the route of the plow. These tracings could be ordered to show how the plow becomes more intelligent.

Beyond ELEC390/49X

The advancement of our project in the future would be large scale plowing of streets. This is a large advancement but will have a lot of opportunity in a new market. A heavy amount of development would have to be done into ensuring these new autonomous plows stay on roadways. Having autonomous snow plows will have a major impact on the world, saving time and money for snow plow drivers, and all other drivers who regularly commute. It will take away jobs from blue- collar workers but also be safer than tired workers who are called early in the day to plow the streets.

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