Real Time Route Optimization

PROJECT PLAN

Team Number: 18
Client: Adam Ryan
Adviser: Goce Trajcevski
Team Members/Roles:

Junjie Wen - Core Software/Algorithm Developer
Zhanghao Wen - Product Manager/Tester
Yuhang Xie – Backend Developer
Xinhe Yang – Frontend Developer
Tianhao Zhao – Communication Leader

Team Email: sdmay19-18@iastate.edu

Team Website: http://sdmay19-18.sd.ece.iastate.edu/

Revised: 10/26/2018 Version 2

Table of Contents

List of Figures

List of Tables

List of Definitions

Please include any definitions and/or acronyms the readers would like to know.

example: ASA: American Standards Association

1 Introductory Material

1.1 Acknowledgement

Our client, Mr. Adam Ryan from Henderson Products Inc., provides us with the overall guidance about the different facets of the problem. In addition, he provides us with the AWS and database runs from the different sensing devices from various components of the trucks for the purpose of enabling a testing of our solutions. In addition, he guides us through the process of representing (i.e., pre-treating) the data about the roadways to help with the route design. For all this, we are very grateful.

We thank our adviser, Prof. Goce Trajcevski, who provides us with valuable advices on our decision and planning throughout the semester.

1.2 Problem Statement

After snowfall, it is important to clear both road segments as well as driveways, so that: (a) travelers safety is improved, and (b) safe access is enabled for employees, customers and suppliers. Car-slip accidents are quite common during the winter months, especially in North America. Thus, an effective management of snow cleaning/removal is of outmost societal importance – however, snow operations impose great costs, both in terms of human labor as well as other financial resources. Our client, Henderson Products, is a custom manufacturer who ensures that their customers (including state departments of transportation, cities, counties, and other governmental agencies) have the most complete snow and ice fighting solutions and service available. Presently, Henderson Products Inc. is seeking a solution which takes advantage of modern Internet of Things and Big Data in order to improve performance of fleets in snow operation and reduce time and financial costs. At the current state of the affairs, our client has limited control and knowledge about the status of the trucks, equipment components, and road conditions after assigning task to fleets' driver. Thus, our team will focus on generating a solution that will allow them to have a better knowledge of the real-time situation of fleets during snow operation, and enable them to perform a more effective decision-making in terms of tasks re-assignments and trucks re-routing.

1.3 Proposed Solution

Our solution includes building a web-based control system that will help our client make an efficient and "smarter" decision. Various sensors have been deployed in the individual trucks of each fleet, and the continuously read data from the trucks and transmit it back to the server. Our system will aim at providing tools for efficient storage and retrieval of such data, along with performing different analytics tasks. We will also enable a visualization of different historical/past data for better monitoring of the fleets' performance and for guiding the operators into selecting appropriate queries to view the data in varying levels of detail. We will also build a cross-platform mobile application as

our supplementary solution which helps fleet drivers to know conditions of their trucks and to communicate with the operators in the headquarters.

We will also work towards designing more advanced algorithmic solutions that can improve fleets' performance in real-time during snow operations with feedback available to our client in a real-time manner in order to suggest driver what level of equipment rate should be set at certain road areas.

1.4 Operating Environment

Our final product is a web application and will be used by dispatchers in Henderson Products Inc. Since it is a web-based design for which the sensing equipment is not directly accessible, the actual physical environment will not be of a direct relevance to our envisioned product, from development perspective. It will require to use specific local and online system with data that fits and operates the software solution from our design.

1.5 Intended Users and Intended Uses

Our project Real-Time Route Optimization is to optimize the route of the snowplow (fleets of) trucks and reduce the resources wasted during the operations. There are three types of users, each with different access and querying and decision-making privileges: (1) general public; (2) fleet member, such as a truck driver; and (3) operator/dispatcher at Henderson Products or DOT, who will have a full access to different data types and processing capabilities, along with the privilege to generate executive re-routing orders. dispatcher or DOT.

For the public view, citizen can access our website to find out the nearby snow plow which displays on map as well as which road has been cleaned.

The dispatcher's task is to assign the route and purpose of each snowplow and return the base to refill the supply if the snowplow has few resources (local resources include: salt, Gasoline and sand, etc.). In this process, the snowplow may pass the same route and cause waste of resources. Our project is to help Henderson's dispatcher to properly distribute the snowplow and maximize resources.

Truck driver can use our mobile application to receive information from dispatcher and local sensor. This software can be used to display the location of the truck and receive instructions from the dispatcher. At the same time, the phone can display the local resources of its own truck, such as the salt and sand in the car, these resources can be transmitted to the phone through the sensors.

1.6 Assumptions and Limitations

Assumption：

- Users will have internet access
- Truck driver will have a cell phone with internet access
- The maximum number of simultaneous users will not be limited.
- Since the main colors on the company's icon are red and black, we will use these two colors on the most of interface.
- The end-product will not be used outside the United States.

Limitations:

- Because our final product is used to provide the best route for fleets, our real-time testing must be carried out during the snowing period.
- The amount of concurrent access to the software depends on the speed of the company's servers and the quality of the software's internal algorithms, so the final software cannot accept a large number of concurrent accesses.

1.7 Expected End Product and Other Deliverables

A web application mainly designed for three types of group. The first group is for public, so citizen can access our website to find out the nearby snow plow which displays on map as well as which road has been cleaned. The second group is driver or member, so they can know what road is assigned to them and their truck condition. The third group has full access to control and monitor fleets during snow operation.

A mobile application mainly designed for driver which allow them to know the condition of truck and road assigned and displayed on map in a more convenient way.

A functional AWS that is capable of transferring data between database and front-end interfaces. For the first semester, our server integrates with front-end website which can help visualize the situation of how fleets operate, what path each truck goes through, what equipment rate and material rate are set at certain road segment. For the second semester, our server will do the calculation and analysis of fleets' real-time performance to actually help dispatcher make assignments and re-route decisions.

A MySQL database which stores all types of data about truck information and users' information. Data could be queried by AWS to monitor and analyze performance of fleets.

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

Develop a cross platform web application for the Henderson Products Inc. The web application will provide a way for dispatcher to create a snow event, assign route to fleet driver, monitor fleet data in a given time period. Data need to be displayed include conveyor speed, spinner speed, GPS location, heading direction, altitude, plow up/down,

material rate. Citizen can also access our website to find out the nearby snow plow which displays on map as well as which road has been cleaned.

Develop a cross platform mobile application for fleet drivers to monitor their own truck supply condition.

2.2 Functional Requirements

- A web application, which must:
    - Display trucks' GPS location on map as well as traffic condition
    - Check out individual truck's supply condition (rate of water/salt dispenser)
    - Historical data can be displayed on the path of each truck
    - Provide all the routes information which is ready to be assigned by dispatcher
    - Allow to communicate with truck driver
    - Allow to open weather condition on certain snow operation area
- A mobile application, which must:
    - Display trucks' GPS location on map
    - Check out individual truck's supply condition
    - Display company's name
    - Allow to communicate with operation center
- AWS server implemented by Nodejs, which must:
    - Generate new route information and send it to front-end
    - Authenticate member/company to login and logout

2.3 Constraints Considerations

One of the constraints that we will have in terms of the non-functional requirements will be upload speed. Path of fleets are generated and represented by a series of dots. Each dot should include all the data mentioned above (GPS, material rate, equipment speed). So one truck will have one path and one snow event will have a fleet of trucks and we also need to store historical data (past snow event). Our client wants us to record dots as many as sensors send to accurately monitor truck condition. Therefore, it is necessary for us to think about how to actually implement our server and website to query from database and display at front end to deal with such a great amount of data.

In addition, concurrent access needs to be considered since many users trying to access may slow down the server as well.

The standard protocols the we will follow while developing our project will follow agile protocol. We have multiple members of our team who are agile certified therefore we will use their expertise to maintain the agile process. The agile process is taught in school in many of our classes therefore they meet IEEE and ABET criteria.

2.4 Previous Work And Literature

Many local governments in areas that get regular snowfall maintain a fleet of snow plows. In the winter season, speed and efficiency of snow plow fleet are of a great importance – especially in highly urbanized cities. Many companies are seeking a solution which takes advantage of modern Internet of Things and Big Data in order to improve performance of fleets. GIS Cloud has shown how to make a snow fleet management system more efficient with a simple software solution in City of Zagreb. They integrate Map Editor and Fleet and Workforce Management, and they also track vehicle in real time and record every vehicle regarding the beginning and ending of the drive, times, miles, fuel consumption, speed limitation, and status of the vehicle, which is similar to what Henderson Products Inc. and our team's are planning to implement.

They also use sensor to capture real-time data. However, the difference is that their sensor is for detecting physical environment like temperature of pavement and air, humidity of the pavements and the freezing point which depends on rainfall, fog and salinity of pavement. Our sensor is focusing more on truck's data like material type, spreader gate height, conveyor speed, conveyor type, spinner speed, spinner pattern. In our solution, we also track GPS and update on map in real time. One function of our solution called "Snow Event" could also report event starting time and ending time.

In our project, our first step is to capture data from sensing devices and visualize information of fleets to inform dispatcher how snow event is going. The major difference is we are trying to improve fleet performance in a detailed manner which care more about the setup of equipment in fleets and the rate change during different road segments.

2.5 Proposed Design

The web application is going to be developed using JavaScript, with the Angular.js framework used on the client side and Node.js used on the server side.

The mobile application is going to be developed with the Ionic framework used on the client side and Node.js used on the server side, our database is s MySQL database.

The Ionic main programming language is TypeScript, which is generally a superset of JavaScript that compiles to plain JavaScript. TypeScript increases the quality of the code because it helps to spot and eliminate mistakes during code typing. Using TypeScript is optional, and the application can be written in simple JavaScript.

The core reason using Ionic is that it provides us high efficiency of coding since the percentage of code reuse among all other cross-platform mobile frameworks is the highest. Although performance statistics is relatively low compared to others, it is acceptable in our project.

The reason we choose MySQL as a platform for our project, is that the maintenance of the data is more important than the actual transaction management (i.e., loading, concurrency, etc.). Given that the main users will be the snowplow driver and the dispatch center, and the data will be loaded from the sensors, the assumption of not being concurrency-heavy seems to be justified at the moment. In addition, this selection allows for easier portability, should there be subsequent developments by the client's teams, after the project has been completed.

Google is used because Google map API can handle a huge number of markers (10000+) at same time and it is more efficient than other map APIs. Our product needs to handle many markers at same time and each of them represents the position of one truck. Many markers mean that when the map is zoomed out, the user cannot clearly see how many trucks are in a certain area. But the google map API has a Marker Clustering feature. It can show the number of markers in a certain area when map is zooming out.

2.6 Technology Considerations

2.6.1 API

We are considering several map APIs including Leaflet, Bing Map, and Google Maps.

Leaflet is a widely used open source JavaScript library used to build web mapping applications.

Bing Maps is a web mapping service provided as a part of Microsoft's Bing suite of search engines and powered by the Bing Maps for Enterprise framework.

Google Maps is a web mapping service developed by Google. It offers satellite imagery, street maps, 360° panoramic views of streets, real-time traffic conditions, and route planning for traveling by foot, car, bicycle, or public transportation.

2.6.2 Mobile Application

Our mobile application is mainly targeted and designed for truck driver, so put different drivers may use different mobile operating system into considerations, we could build iOS app by using Objective C and Android app by using Java.

Figure 1: mobile app framework comparison

We note that we could also build a hybrid app. A hybrid app is a program that is built using HTML 5, CSS and JavaScript and wrapped in native container which can used in different platforms. We have choices like Xamarin, Ionic, Native Script framework. We expect to make a final selection based on the interaction with the client in the next two weeks.

2.6.3 DATABASE

Development: Mongo dB is a rather friendly environment for development because of its supply of JSON format data. With the Mongo DB, developing speed can get improved. For MySQL, it is a more mature solution. There are lots of documents about MySQL. Besides MySQL is also extendable for different data type in the future. So, for development, MySQL and Mongo DB does have significant advantages than the other one.

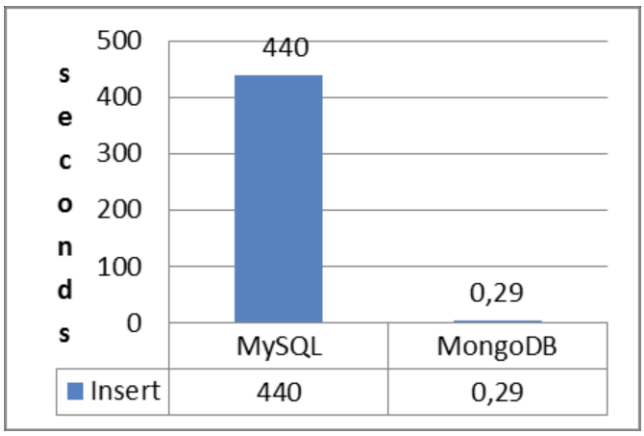

Figure 2: MySQL vs MongoDB

Maintenance: relational database is very good for maintain because the rules in operation on table. On the other hand, no-relational database is not easy to maintain, and more risk in illegal operation on database. So, for maintain, MySQL is also friendlier to engineer.

Load: Compared with MySQL, Mongo DB is better on loading.

2.7 Safety Considerations

Our team does not have many safety concerns due to having limited hardware components needed to use our project. The only safety concerns we have is for our driver to be operating trucks while using our project.

Considering Cyber-Security problem, there are two factors we need to pay attention. First, we need care about the data security. Different company shall not see another groups' information. Second, we need consider snowplow driver's security. The route we give should be safe to work.

2.8 TASK APPROACH

Our design thinking process shows as Figure 2 below.

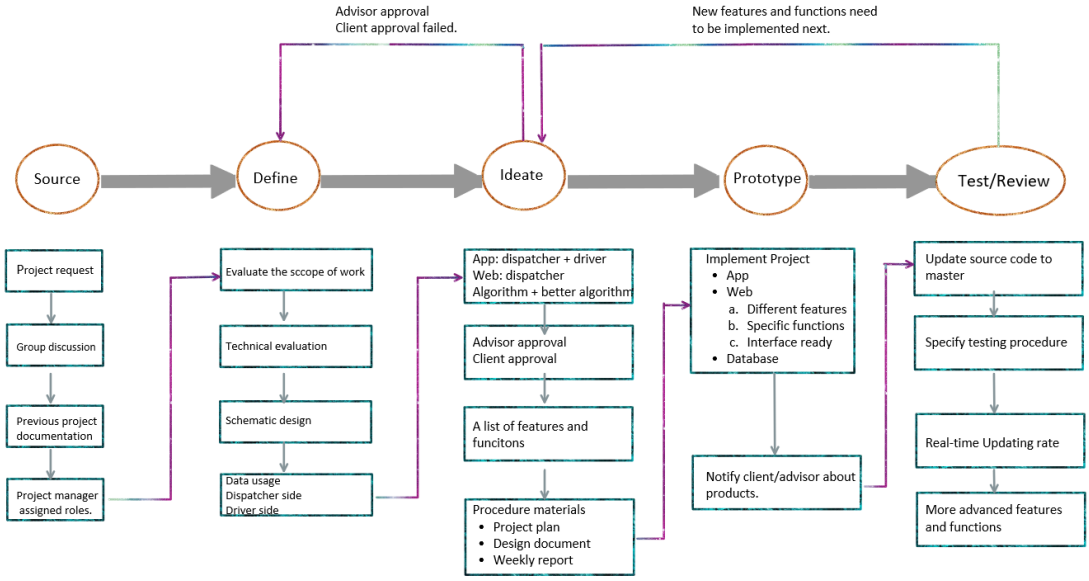

Figure 3: Designing Thinking Process

For display of the features and real time conditions, we create the frontend interface of both web and app for easier control and monitor during snow operation. There is a simple of tasks relations how we collect, use and display data in Figure 3.

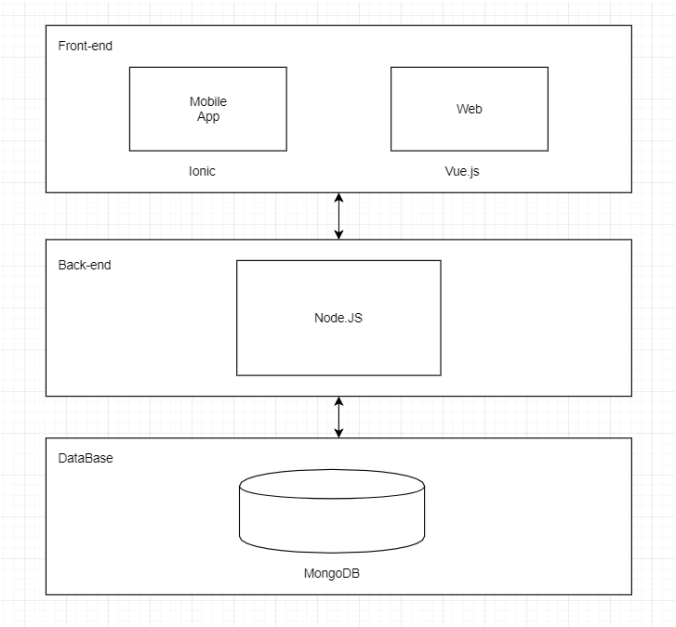

Figure 4: Relation of Designing Tasks

2.9 Possible Risks And Risk Management

After analyzing the entire software architecture, there is a framework risk theme for our project. First of all, probably there is a security risk. Our sensor data is stored in the database. In authentication and authorization, data is transferred between the client and the server. However, the data is not securely encrypted. If data is intercepted during transmission, this security risk will result in the user's information being easily leaked and used. The amount of traffic to our data could be very large, which can affect server performance and interface access speed. And the communication between the servers is very expensive. In accuracy, the sensor on the truck may be affected by factors such as the weather, so the accuracy of the data we return will be reduced. Therefore, we should carefully analyze these existential analyses and get improved methods.

2.10 Project Proposed Milestones and Evaluation Criteria

- Make sure what framework and API need to be used
- Gather data from sensor, store, process, convert, and display data at front end interface
- Display data at certain points in truck's path which is generated by GPS
- Accomplish three types of view for 3 types of user
- Define road priority and help dispatcher make decision
- Automated process which can fully guide and help dispatcher make decision and assigning real-time re-route for fleets

2.11 Project Tracking Procedures

We are using a Trello board to record the progress of project and Minutes of Meetings with our client and advisor. We also use Trello to track which task is ready to be picked up, which tasks are assigned to different team members, what tasks have been completed.

Our teams write weekly report that detail individual work that has been done and our overall team progress in each week.

We have a phone meeting with client every week to update our progress. Client and our team ask question to each other to help us clarify current issues, popular solutions existing in the world, and project specifics.

We also have a communication leader that lead us to discuss course deadlines, assigned tasks, prepare presentation, and a project manager to make project decisions.

2.12 Expected Results and Validation

Our desired outcome is to have a fully working product that meets all of our functional and non-technical requirements. We believe that if we meet all of our requirements and scope which have been refined by our team multiple times and recently approved by our

client the product will be satisfactory. The client has requested a web application that mainly used for management level which will be able to see path that fleet go through in each snow event as well as displaying various of data once clicking on certain point on path. Our team will try to design and implement more advanced algorithm to make real-time re-route an automated process, which is easier for our client to control fleets, reduce costs, and improve performance.

2.13 Test Plan

Unit test: A bunch of unit tests should be built, which will cover all platforms, including android, IOS, front-end and back end code. And should be executed every time the code be changed.

Integration test: There should be individual integration test for different platform, including Android, IOS, Front-end and Backend.

System test: Test engineers should implement test code based on black box test policy.

Acceptance testing: The whole team will work on final evaluation of acceptance.

3 Project Timeline, Estimated Resources, and Challenges

3.1 First Semester Timeline

The following is a Gantt chart outlining the proposed timeline for the project's development through the first semester. The blue bars indicate project phases

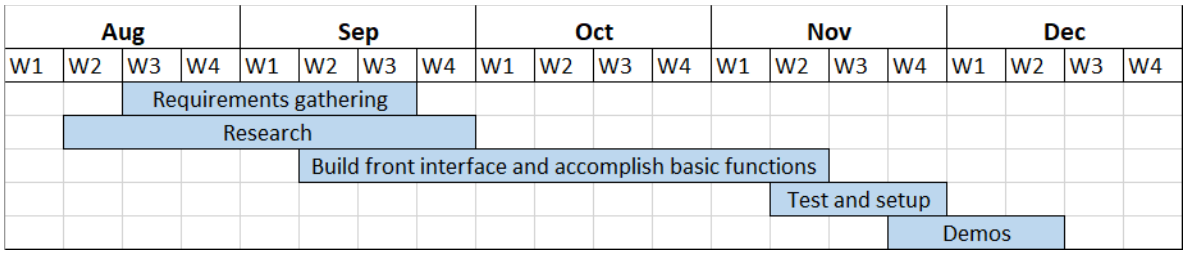

Table 1. First Semester Timeline

The first few weeks of the project, we will spend time understanding the requirements, researching, and prototyping. Most of our design thinking happens here and we make sure to meet with the client often in order to get the requirements. After the first few weeks, we start working building front end interfaces, including a web page and a cross-platform mobile app to make dispatcher side (manager) of snow operation "smarter" by showing truck condition at certain time points in its path.

Basic functions of our project are going to be implemented and tested before the end of first semester. More work for the advanced data analysis from various algorithms will continue into the next semester.

3.2 Second Semester Timeline

The following is a Gantt chart outlining the proposed timeline for the project's development through the second semester. The blue bars indicate project phases.

Jan				Feb				Mar				Apr			
W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
Analyze and design advanced algorithm															
				Implement new functions											
									Deployment						
						Testing, Validation, Polishing									

Table 2. Second Semester Timeline

The plan for the first 2 months is to continue working on the web and mobile application to help dispatcher to monitor fleet of truck during snow operation. At this point, data from client is probably more detailed and we need to design more advanced algorithm based on various real-time scenario to help dispatcher make decisions.

3.3 Feasibility Assessment

Basically, this project is divided into 2 parts in 2 semesters. We expect to have a fully functional, production ready, mobile application as well as web application by the end of second semester. Our system will employ the use of a frontend backend architecture allowing our team to make changes to either system without the need to change the other.

We expect to have all the basic functional requirements met at the end of first semester, and it includes web pages with 3 types of map view for 3 groups of users: public, member, and full-access dispatcher which give information about fleet at different level. Therefore, we need to think about permission and how they can access different pages. Once snow, dispatcher can create a weather event by our website which can send route and other related information to driver. What's more, dispatcher can access to our webpage and see the path that fleet go through and click certain point on that path, data like spreader speed and plow height will show up. This will help central manage office monitor performance of fleet.

Our first challenge is that data is given later than what our team expected, which we build our own data simulator to generate the data we need.

Another challenge in the future will be that there will be so many aspects that we need to consider and analyze and apply those data into re-route algorithm. The aspects include traffic condition, which may affect some trucks' working time, weather, which leads to

snow plow spreader rate, gate height setup, spinner speed, etc. Another important aspect is road priority. Once operation started, we need to determine which roads within snow operation area, including roads in rural area, main road in a city (for example Lincoln way in Ames), and highway, have what level of priority.

3.4 Personnel Effort Requirements

As seen below, Table x is a table of the major tasks that we need to accomplish and implement in order to complete our project. In addition, we also have workshops, preparing project presentation, listening tech-talk, research, and documentation.

Task	Description	Estimated time
Create Requirements	Create a list of the requirements needed for the software	10 hours
Research	Background information and software tools analysis, framework, and API choice	20 hours
Design algorithm	Design the data analytics algorithm. Improve algorithm based on new types of data	20 hours
Front-end application	A web page designed and implemented mainly for central manage system and a mobile application designed and implement for end-user	40 hours
Transfer Data	Get data communicate between database, server, and front-end application	20 hours
Design database architecture	We will need to create a database that can manage the different types of information along with dealing with the large amount of data	20 hours
Testing	Test accuracy of the algorithm or improved algorithm	15 hours

Table x: Major Tasks

3.5 Other Resource Requirements

- External resources to maintain the team's documentation and Git instance.
- Sensor from Henderson for testing
- Google map API
- Weather API

3.6 Financial Requirements

The main financial resources needed to complete this project are minimal during the development cycle with our team only needing one server to host both our frontend and backend. Our client provides us AWS (Amazon Web Server) and it costs $650 per year. At this stage, all the software that we will be using to implement our solution is free for us to use.

4 Closure Materials

4.1 Conclusion

The overall goal of our project is to reduce time cost and financial costs and improve efficiency of fleets of snow plow during snow operation. The major problem our client is facing is that they have limited control of fleets of truck once dispatcher assign which roads they need to clean. Based on weather condition and different types of road, driver should setup equipment rate differently. In order to monitor and guide truck driver, we deployed sensors in fleets which can read all data and send them back to client, so they can analyze and improve fleets' performance in the future. We are currently working on the interfaces where the client can access that information.

Or even better in the next semester, we will think about and design more advanced algorithm that can improve fleets' performance real-time during snow operation with feedback available to our client in a real-time manner.

Real time data from sensors deployed in each truck will be took advantage to analyze decision of real-time reroute. MySQL is used to communicate and store data from AWS server which is provided by Henderson Products. Main interfaces of our projects will be achieved in two form: web application and mobile application. Mobile app will be built for snow driver to ensure that they understand condition of truck such as supplies (sand, salt). Web will be built for dispatcher and manager who oversees overall snow operation and send assigned routes or reroutes information to drivers.

4.2 References

https://medium.com/@TechMagic/reactjs-vs-angular5-vs-vue-js-what-to-choose-in-2018-b91e028fa91d

https://www.altexsoft.com/blog/engineering/xamarin-vs-react-native-vs-ionic-vs-nativescript-cross-platform-mobile-frameworks-comparison/

https://www.denvergov.org/pocketgov/?utm_campaign=colorado.ourcommunitynow.com%20website&utm_source=ocn_story&utm_medium=website&utm_content=%E2%80%98Plow%20Tracker%E2%80%99%20website#/plowtracker

http://www.hendersonproducts.com/about_us.html

https://disastersafety.org/ibhs/snow-removal-is-essential-to-keep-a-clear-path-to-your-business/

https://www.giscloud.com/blog/fighting-the-snow-with-a-fleet-management-solution-a-case-study/

https://www.eastbanctech.com/binaries/content/documents/site/technology-insights/what-the-tech/files/transforming-snowplow-fleet-operations/transforming-snowplow-fleet-operations/site%3Afile

https://certifiedcirus.com/wp-content/uploads/2017/04/Certified-Cirus-Winter-Road-Maintenance-Data-and-Reports.pdf

4.3 Appendices

No data available at this time.