Multi-Disciplinary Senior Design Conference
Kate Gleason College of Engineering
Rochester Institute of Technology
Rochester, New York 14623

Project Number: P11015

MOBILE LANDMARK IDENTIFICATION

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ABSTRACT

The primary goal of this project is to design a portable device that assists visually impaired and blind persons to select a desired bus and find the exact location of that bus at a bus stop. This device will ultimately enable the VIBP to board their chosen bus with minimal outside assistance. The first phase of the project is a proof of concept that focuses on identifying buses and guiding the user to them. The completed system will be a portable device that is able to locate buses and guide visually impaired and blind users to the correct buses through tactile prompts.

This project specifically focuses on the software portion for mobile landmark identification and navigation. This is done using GPS information alongside an accelerometer and a compass. These parts of the projects will be discussed in the *Process* section.

NOMENCLATURE

VIBP - visually impaired and blind persons
RGRTA - Rochester Genesee Rural Transit Authority
DOF – degrees of freedom
MSD – multidisciplinary senior design
GPS – global positioning system
RFID – radio frequency identification
CE – computer engineer
SE – Software engineer
IT – Information technology
T.I.D.E – Technology Initiatives for Driving Excellence. Part of RGRTA.
DCM – Drift Correction Matrix
g – Standard Gravity or 9.81 m/s^2
RX – Receive
TX – Transmit
VDC –Direct Current Voltage

INTRODUCTION (OR BACKGROUND)

Past projects include the CE project that predicted arrival times for buses by utilizing web enabled GPS technology. Projects P11016, the Intra-building Navigation, and P11017, the Tactile Interface for the Visually Impaired, are both running in parallel to this project and in the long term will be integrated into one device that can perform both functions (identifying mobile and static landmarks).

Initially, a member of the Association of the Blind and Visually Impaired (ABVI) brought to the attention of one of RIT's faculty members that VIBPs have an immense difficulty identifying the correct buses at bus stops. Specifically, the only way they have been able to find the right information would be by asking the drivers about the bus' destinations. This method has many disadvantages due to time consumption because bus drivers have to keep time and run on a schedule pre-determined by RGRTA. This meant that the VIBP had to rush to the buses to ask for information regarding the final destination within a very short time while others were boarding the bus.

The problem was brought to professors within the Engineering Department and a project was proposed to the team to pursue. The team began researching the project in the form of specific interviews with two VIBP students who could elaborate on their experiences and difficulties with public transit systems around Rochester, NY. This dialog helped the team better understand the problem within the correct perspective so that actions could be taken to form a project plan.

Immediately after these discussions it was brought to the team's attention that Rochester's main mass-transit authority, RGRTA, was interested in a very similar issue dealing with its own system. It was proposed that the team work alongside RGRTA towards a common solution to the problem. However, RGRTA's team was headed in a different direction in terms of technology selection and their approach to the problem. This limited the amount of collaboration between the teams, but RGRTA was willing to provide the team with access to their GPS database as well as providing the needed information and data stream.

PROCESS (OR METHODOLOGY)

Functionality Definition and Project Focus

In order to design a product with the right specifications, the team went through the proposed project document. After going through the document and dissecting it, the team decided the path of this project.

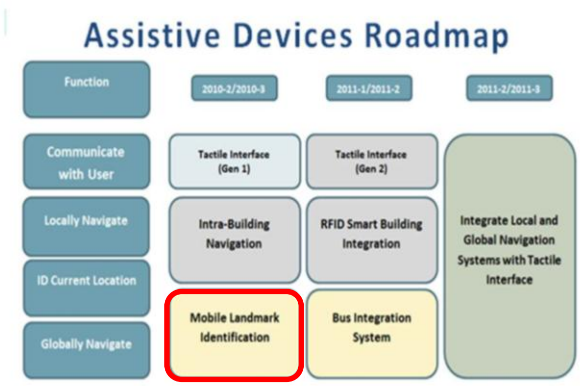

Figure 1 Family of projects for assistive devices

This project focuses on the software portion that includes mobile landmark identification and navigation. This software package will provide a vector that can be incorporated into the combined device that is projected to be an integration of this package of software as well as the static landmark identification package, P11016, which is running in parallel with this project. These packages will both be integrated in coming iterations of this family of projects into a stand-alone hand-held device.

This meant that the team had to define the functionality that is desired from the software package. This package had to be able to identify buses, allow for desired bus selection and then navigate to the desired bus. It should also be able to recalculate and notify the user if the given path has changed. For this iteration, the output will be visual in order to compare the software output to the actual distance and direction given.

Assumptions

Blind and visually impaired individuals face difficulties identifying the correct buses to get on at a bus stop. This team aims to enable those individuals to identify the correct buses on their own within a shorter time frame.

After several interviews with VIBPs and individuals who work closely with VIBPs, the following assumptions were made in order to simplify the design and decision-making process. These assumptions include the use of one specific identification method. The VIBPs are capable of getting to the bus stop without assistance and have minimal addition sensory loss. This iteration focuses on the Gleason Circle bus stop at RIT, but will be developed in a way that allows for it to be applied elsewhere with minimal change or modification.

Constraints

Once these assumptions were agreed upon, the team agreed on a list of constraints. This allowed the team to determine the proper time-line as well as deciding which technology path to take due to these constraints.

These constraints include the 22 week time constraint as well as the $1500 budget constraint. This project focuses on software development for identification and navigation. No hardware can be installed on the buses. The bus drivers are union drivers and cannot .do anything outside of their union regulations without permission from the union. The buses have a fixed stop schedule and each stop time is approximately one minute according to the schedule.

Design Decisions

Static starting point identification

In order to simplify the integration of projects down the road of this family of projects, the team decided to collaborate with the static landmark identification team, P11016. The teams agreed on using RFID tags and an RFID tag reader in order to identify static landmarks, like the starting point at the bus stop. The testing done will be discussed in more detail in the *Testing* section.

Bus identification

Bus identification is done using the GPS information streamed over an internet connection, most likely the RIT wireless network, from the RGRTA GPS database.

Bus navigation

Bus navigation will also be done using the GPS information from the RGRTA database. The software package will compute a vector and a direction to output to the user. This output will be incorporated into the integrated device in the third generation of this family of projects.

Path correction

The path correction algorithm is based on using a grid system with two axes and an angle computed from north to the vector calculated. This is done using the 9 DOF RAZOR IMU unit, which is a 3-axis accelerometer and compass unit with 9 DOF. This algorithm computes and outputs a new vector for the user based on the estimated location of the user using numerical integration to provide the most accurate vector possible with the information collected.

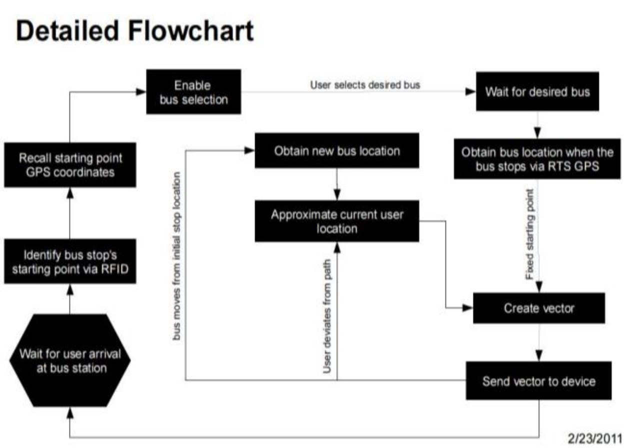

Figure 2 Detailed Design Flowchart

TESTING

Bus Time Zone and Delay

The buses were observed and timed over a few weeks to understand the time it takes the bus between entering the GPS pick-up area and leaving the bus stop. This was done by averaging the times using a simple average calculation.

RAZOR IMU Unit Testing

The 9 degrees of freedom (9DOF) Razor IMU board incorporates four sensors; two gyroscopes (LY530AL and LPR530AL), an accelerometer (ADXL345), and a magnetometer (HMC5843). The outputs of all sensors are processed by an Arduino compatible on-board microcontroller, ATmega328, and output over a serial interface. Note that the board comes with the on-off control switch and reset switch. One end of a six-pin right angle male strip header was soldered to the serial TX and RX pins of the Razor IMU board while the other end is connected to the FTDI basic breakout. The jumper of the breakout board was set at 3.3 VDC which is the supplied power to the Razor IMU board. The mini USB to USB cable was used to connect the setting to the computer unit.

Preliminary Testing: Under Arduino IDE environment, the board type was selected to be Arduino Pro or Pro Mini with ATmega328. The test firmware code, developed by Jose Julio, was uploaded to the Razor IMU board. The data was extracted and visualized under Python environment with VIDLE add-on. The functionalities of the Razor IMU were determined based on the data.

Accelerometer Calibration: The ADXL345 datasheet estimated that the accelerometer would read on average 256 steps for 1g (a standard gravity). Since the transfer ratio provided in the datasheet is only a statistical approximation, thus an actual accelerometer calibration was conducted for this specific Razor IMU board. Utilizing the earth gravity, the accelerations were repeatedly measured when Razor IMU board was placed in YZ, XZ, and XY plane representing earth gravity in x-, y-, and z- axes respectively. The statistical analysis was conducted to determine the transfer ratios for all axes. The same method was taken to determine the measurement offset between all of the positive and negative planes (i.e. YZ and –YZ planes).

Gyroscope Utilization: The test firmware code developed by Jose Julio contains a drift correction matrix (DCM) code for gyroscopes which could be appropriately utilized. The DCM code was then added to the prior developed acceleration code. With available data from the accelerometer and gyroscopes, the magnetometer code could be developed to accurately determine magnetic heading.

System Speed Optimization: Function millis() in the Arduino environment was used to calculate the time period between each set of data output. Parts of firmware code that is not absolutely necessary to the user position determination was taken out or adjusted to minimize the time period between dataset.

User Position determination: The velocity and the position in x-axis (adjusted to the North) and y-axis of horizontal plane was calculated using Riemann sums as shown in Equation (1) and (2) below. Note that s is displacement, v is velocity, and a is acceleration. The actual test must be run to test the accuracy.

$$v_x = \sum_{i=0}^{n-1} t_i a_{xi} \text{ and } v_y = \sum_{j=0}^{n-1} t_j a_{yj} \ldots (1)$$

$$s_x = \sum_{i=0}^{n-1} t_i v_{xi} \text{ and } s_y = \sum_{j=0}^{n-1} t_j v_{yj} \ldots (2)$$

RFID Range Testing

Different Angles from Antenna (Indoor)
Five different Alien RFID tag types, named after their respective antenna type, were initially tested for read range distance: 1) "G" inlay, 2) "2x2" inlay, 3) "Short" inlay, 4) "Squiggle" inlay, and 5) "Squiglette" inlay. Testing with the "Squiggle" and "Squiglette" tags was stopped when they were not detected by the reader. The other three tags were detected from an average distance of 40" between 0º and 90º and between 150º to 180º. All tags produced a dead zone (an angle range in which the tags were not detected) between 90º and approximately 135º. This dead zone was largest when using the short inlay tags (75º to 150º). The G inlay Alien RFID tags were the most reliable with the highest read range (>45") and the smallest dead zone (90º to 135º).

Different Wall Materials (Indoor)
Tags were mounted on glass, a door window, Plexiglass, plastic, brick, painted brick, metal, a metal door, an elevator door, a wood plaque, wood, the cement floor, and drywall one-by-one respectively. The "G" inlay RFID tag performed best on brick, while the "2x2" and "Short" inlay tags performed best on plastic.

Different Heights (Indoor)
The "G" inlay tags were placed on brick and the "2x2" and "Short" inlay tags were placed on plastic. The reader was held approximately four feet from the ground, parallel to the tags at one foot, two feet, and three feet distances respectively. The reader was then moved up/down vertically until the tag was out of read range. This distance was recorded and the angle was found by calculating the inverse tangent of the vertical distance divided by the horizontal distance from the tag. The "G" tag was read consistently from one foot away, with an average upwards angle of approximately 38º and an average downwards angle of 45º. The "2x2" and "Short" tags read at one foot away with average upwards angles of 60º and 56º, and average downwards angles of 70º and 55º respectively.

Bus Stop Testing

Different Angles from Antenna (Outdoor)
To test the effect of attaching the RFID tags to meta.l, five different Alien RFID tag types ("G", "2x2", "Short", "Squiggle", and "Squiglette" inlay) were mounted to wood and plastic, and this assembly was then attached to the bus stop pole. Read range angles and distances were recorded.

When mounted to a 1.5" thick piece of wood, the "G" and "Squiggle" tags were detected throughout the entire testing range of 0º to 180º at an average distance of one foot. Both of these tags were also consistently read at a 30º angle above and below the point parallel to the tag height.

When mounted to a 1" thick piece of plastic, only the "G" tags were detected. Although further testing was done, it was decided early that this was not the best method combination of tag and mounting material.

Vector Calculation and Error
The vector is calculated using the haversine formula to determine the distance between two points, using GPS coordinates in this case, as well as a heading of the vector using a reference distance using the North-South facing Gleason bus stop to calculate an angle to give the direction of the vector.
Error calculation is done through field testing of the algorithm.

Field Testing
Field testing consists of combining all aspects of this project into one comprehensive test. This means that the RFID navigation to the starting location will be tested alongside the bus selection, navigation and the path correction algorithm. This will allow for the team to assess the overall functionality and efficiency of the system designed and built. This is done using the RFID reader mentioned, the 9 DOF RAZOR IMU unit and the netbook.

SOFTWARE DESIGN AND IMPLEMENTATION

The Software00 was written in C# and created in Microsoft Visual Studios 2010. The entire project consists of six classes: three object files to hold and organize important data named Bus.cs, TimePoint.cs, and GPSCoord.cs; two threaded classes to gather data from RGRTA named timepointData.cs and Busdata.cs; and a main program to run the guidance algorithm named vipbGuidance.cs.
The two threaded files to gather the data are labeled timepointData.cs and BusData.cs. The first gathers only the specific time point that each bus hits on the RIT route. The second gathers the information of the regular GPS signal that each bus sends out at a rate of

once per minute. This information is stored in two Dictionary objects one that stores each Bus according to its route, which is determined by the time-points it hits. The other stores the bus by its id number with its most current GPS location.

As per their names the object classes store relevant information about each object. The Bus object stores the ID number of the bus, the buses last GPS location, the route it has been assigned to and the last time point it hit. The TimePoint object stores each time point as a String for its name and a GPSCoord of its location. The GPSCoord object is made up of two doubles for latitude and longitude.

The vipbGuidance class works by first prompting the user for a destination until a valid destination is entered. Then that route is searched for until the correct bus is identified. Once it has been identified it waits for the arrival of the bus to the timepoint of the user. Once the bus arrives a new GPS signal is sent a minute after it arrives from which the Haversine Formula is used to compute a direction vector to guide the user. If the user deviates from the path a new vector is calculated. The program exits when the bus leaves the timepoint.

RESULTS AND DISCUSSION

Bus Time Zone and Delay

This test yielded an average of 40 seconds between the bus entering the time zone until it reaches the bus stop and approximately 1 minute of stopping time at the bus stop. These results show that the use of the GPS time zone is adequate to determine the location of the bus once it stops at the bus stop due to a 60 second refresh rate for the GPS location of the bus.

RAZOR IMU Unit Testing

The completed Razor IMU unit, comprises of 9DOF Razor IMU, FTDI breakout board, and mini USB to USB cable is shown in **Figure 3.**

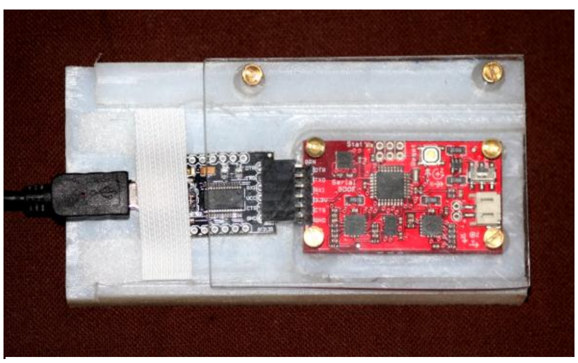

Figure 3: The 9 DOF Razor IMU Unit

Preliminary Testing

The test has confirmed the functionalities of the 9DOF Razor IMU unit. Note that its visualization of the output data (Euler angles) is shown in Figure 4. The results present certain amount of inaccuracy in the output data which must be corrected in the following tests.

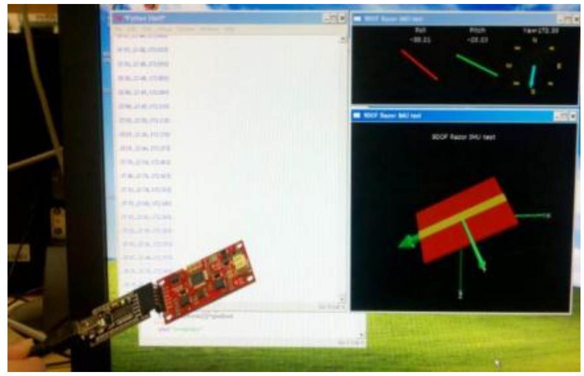

Figure 4: 9 DOF Razor Unit movement visualization from the preliminary testing

Accelerometer Calibration

The Accelerometer Calibration firmware code was uploaded onto the Razor unit. The test was done for each calibrating axis by limiting the earth gravity reading in non-calibrating axes to minimal as possible. After statistical analysis, the accelerometer transfer ratios for x-, y-, and z- axes are 315.98, 314.63, and 290.18 steps per 1g respectively. The preliminary testing also shows that between the positive and negative measurement on each axis are not equal. The offsets are need for each axis to adjust for the issue. The data was taken from positive and negative direction for all axes on-by-one. The negative direction offsets for x-, y-, and z- axes are -2.495308, -7.162633, and -25.68013 steps respectively.

Gyroscope Utilization

The adaption of DCM to the original code was successful. However, since the firmware code did not adjust for the upside down measurement, the appropriate roll and pitch angles must be limited to ±80 degrees. The magnetometer was successfully enabled and the magnetic heading or yaw angle was found to be accurate to within ±5 degrees in the horizontal plane. From the tests, any ferrite metal (i.e. iron and stainless steel) could interfere with the magnetometer performance; it is recommended that the Razor unit must be at least 6 inches away from those ferrite metals.

System Speed Optimization

Prior to the optimization, the time period between data set was found to be approximately 125 - 130 milliseconds. After the optimization, the time period was reduced to approximately 15 - 17 milliseconds.

User Position determination

The Riemann sum equations were proven to work correctly. However, issues arose when the Razor unit rotated in any direction (in other word the roll or pitch angle was not equal to zero) due an in ability to deduct the earth gravity out from the measurement data. Thus, the position determination was developed specifically when the Razor unit moves in the horizontal and is not tilted.

RFID Testing

RFID Read Range Testing (Indoor)

After reviewing the preliminary RFID tag read range results it is recommended the "G" inlay tags be mounted on plastic at a distance from the ground of approximately 3 feet.

Bus Stop Testing (Outdoor)

After reviewing the RFID tag read range results, Figure 5 to Figure 9, at the bus stop, it is recommended the "Squiggle" inlay tags be mounted on a 1.5" wide piece of wood at a distance from the ground of approximately 3 feet. The "G" tags can be used also, but the "Squiggle" tags were selected because their range of detection is sufficient for identifying the bus stop.

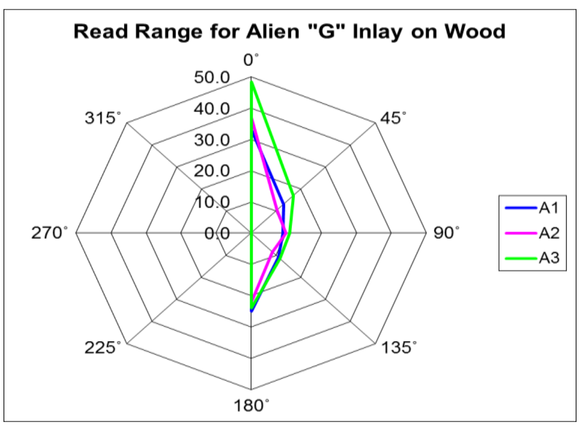

Figure 3: Read range for the "G" inlay on wood

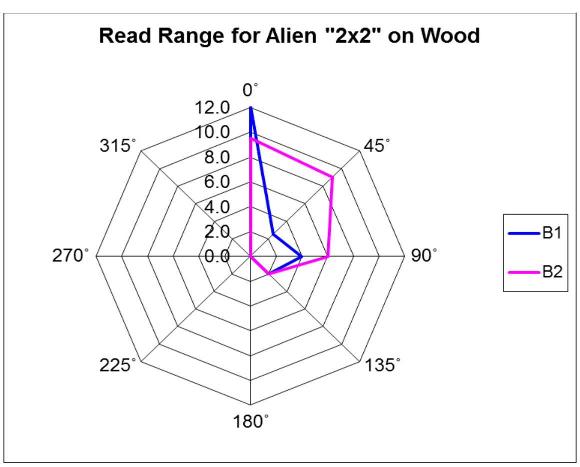

Figure 6: Read range for the "2x2" inlay on wood

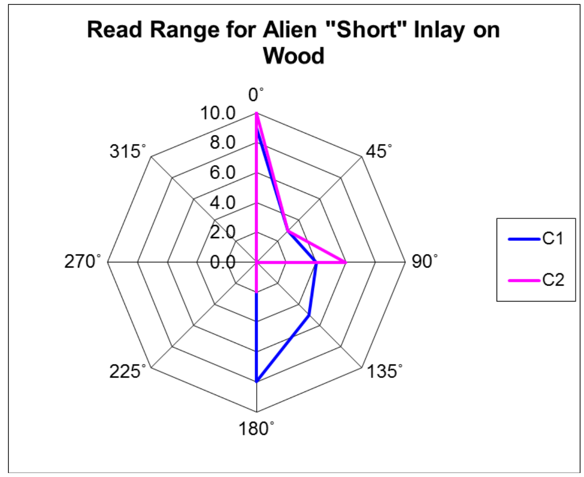

Figure 7: Read range for the "Short" inlay on wood

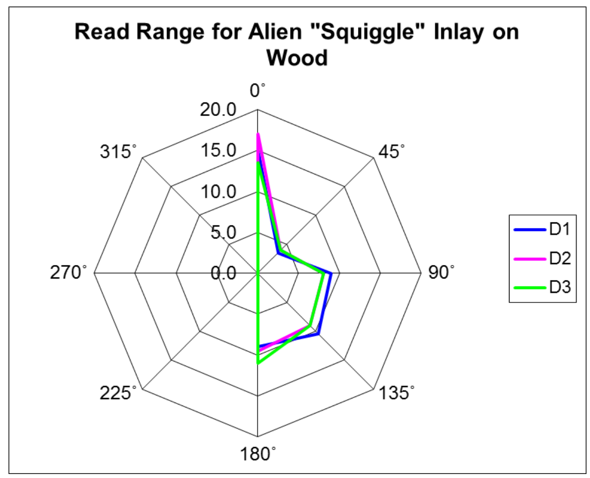

Figure 8: Read range for the "Squiggle" inlay on wood

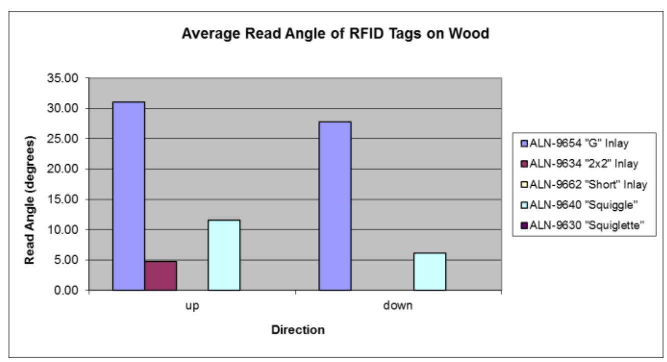

Figure 9: Average read angle of RFID tags on wood

CONCLUSIONS

This project has yielded some good and positive results. In terms of higher level project objectives, the software package can successfully identify buses and navigate to a selected bus. The vector calculation algorithm can calculate vectors that are accurate within x feet. The path correction algorithm is relatively accurate for this application.

RECOMMENDED FUTURE WORK

In future MSD projects, specifically the family of projects revolving around this device, the primary goal should be to design, build and control the device easier without needing customer to face at a certain direction or fixed position. The next iteration of this project should be focused on building a more user-friendly device that is more efficient as well as being lower maintenance than this iteration's outcome.

This portion of the project is mainly focused on software development. This means that the next iteration of this specific portion should include the following majors:

- CE: for overall development and concept generation at a higher level
- SE: for software development and interface improvement
- IT: for network and connectivity
- EE: for RFID testing and improvement.

The team should work more closely with RGRTA in order to ensure the proper development within RGRTA's limitations as well as ensuring the implementation of the device once it's built and tested. The speed of the system should be improved as well to account for real-time changes instead of being only capable of one update per minute.

In terms of using an accelerometer and compass unit to account for path correction, the best path is to acquire a combined unit instead of acquiring each separately and finding ways to interface the two. It is also recommended to use better hardware for path correction and location determination. The algorithm used for new location determination is very crude because it is based on a numerical integration using Riemann sums. Applying a more accurate method would be recommended in order to avoid error propagation through the two integrations.

For RFID tag selection, passive tags that are designed to work when placed on metal are recommended if the project were to be applied on a larger scale. This will decrease the need of items to be purchased and machined for the tags to function properly.

Adding another feature to the software portion that verifies bus selection and then the bus when the user arrives at the selected bus is also recommended in order to ensure the user arrives at their desired bus.

The software should be improved to be more robust and flexible to accommodate for any bus stop alongside the Gleason Circle. Possibly having team members that is familiar with MS Visual Studios and MS SQL Server with Server Management Studios would definitely simplify the process because those software packages are what the team would need if they choose to work with RGRTS's database.

Another recommendation would be for this package to be integrated into a device that is already in use, like a smart phone or cell phone, instead of building a stand-alone device.

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