Design and Implementation of an Algorithm for Multi-Environment Position Tracking

Ryan Lee Tonini

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Design and Implementation of an
Algorithm for
Multi-Environment Position Tracking

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ABSTRACT

A need exists for a product with which users can track individuals inside and outside of buildings. GPS devices require signals from satellites in order to produce an accurate calculation of position. Buildings obstruct GPS signals. This is undesirable in situations where, for instance, emergency response teams are required to enter hazardous situations occurring inside buildings. The goal of this project is to develop an algorithm that can create tracking devices that are not only usable outdoors, but indoors as well. Following the development of this algorithm, a system is also to be created that utilizes this algorithm. With this system, named DRS, many individuals can be tracked simultaneously, allowing for the tracking of soldiers in Baghdad, firefighters in a burning building, or parolees in our cities.
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1.0 Design Problem

Global Positioning System (GPS) devices require signals from satellites in order to produce an accurate calculation of position. In many situations, buildings, bridges, or anything blocking line of sight to the sky can obstruct GPS signals. This is undesirable for situations in which emergency response teams are required to enter hazardous situations where their location is crucial information.

The need that this project addresses is the ability to track individuals within and around buildings where GPS services are not available. This should be accomplished using a single device that dynamically switches between GPS and Dead Reckoning operating modes. In GPS mode, the device will operate as any normal tracking device would. In Dead Reckoning (DR) mode, the device uses the measurement of physical movement to estimate speed, distance, and direction. The device should immediately send its position data to a PC for real-time tracking and mapping. This project intends to develop a product that can be sold to consumers.

1.1 Usefulness/Health and Safety Impact

There are several applications where this device would be useful. They include military, law enforcement, firefighters and miners. Our project is meant to save the lives of those who put themselves in danger. Use the mapping application at your fire truck to monitor the location of firemen inside of a burning building. If your soldier goes down from a bullet wound in a building in Baghdad,
immediately know where he is located within the building so that you can rescue him directly. With this product, you will not waste time trying to pinpoint his exact location.

2.0 Research

There has been an extensive amount of work done in the field of position tracking. Some of the work is noted below.

2.1 Alternative Techniques

Acceleration in the direction of movement is the technique used in this project to track an individual’s location. However, several other techniques can be used to determine position.

One technique is triangulation, which uses radio frequency (RF) beacons to determine location. This technique uses RF tower intercommunication to triangulate position. A disadvantage to this technique is the necessity of the existence of RF towers near the location of the individual.

Another technique is step detection, which identifies a step based on accelerometer readings in the up/down axis. A step is associated with an estimated distance. The estimated distance is found by calibrating the algorithm for an individual’s walking pattern. Calibration is a disadvantage of step detection because the device cannot be easily transferred to another person for use. Every individual has a different walking pattern. One person may take small steps while another person takes much larger steps. In fact, the same
person may take small steps one day, but if he is in a hurry, he may take larger steps on another day. These factors limit the correctness of a device using a step detection algorithm.

2.2 Existing Products

Several products have been previously developed to address the problem of tracking individuals. Honeywell produces a large selection of Dead Reckoning products that are currently available on the market.

DRM-III OEM Dead Reckoning Module for Personnel Positioning is a product that is a self-contained electronic navigation unit that provides the user's position relative to an initialization point. This module consists of a tilt-compensated magnetic compass, electronic pedometer, and barometric altimeter. These sensors provide a continuous deduced position calculated by a microprocessor. A Kalman filter and other algorithms use the GPS data, when it is available, to calibrate the Dead Reckoning sensors. This provides a Dead Reckoning accuracy of 2% to 5% of distance traveled. This module has an 8MB data logging memory that can be downloaded to a personal computer. There is not a real time position tracking capability for this device.

DRM 4000 Dead Reckoning Module is another product that is also produced by Honeywell. It is priced at $1695.00. This module is meant to be used by personnel on foot and to provide the user's position data relative to an initialization point. The DRM 4000 blends Dead Reckoning data with external GPS data in an internal Kalman filter. Patented motion classification algorithms
are used to analyze walking motion. These algorithms will compensate when the user is running. Gyroscopes are used to compensate for temporary magnetic disturbances that can interfere with the compass operation. This module implements three gyroscopes, three accelerometers, and three magnetometers. It also uses a barometric altimeter to calculate vertical position. In addition, this module can be interfaced with a GPS receiver to supplement position data. However, a GPS receiver is not integrated within the device itself, it must be purchased separately and attached manually.

Another product that is produced by Honeywell is the DRMcore Dead Reckoning Module, which is priced at $900.00. This module is intended for use by personnel on foot and provides 2-dimensional horizontal navigation and compass azimuth. It does not include an altimeter or GPS receiver on the circuit module, but will accept external GPS position input from a user's GPS receiver.

Honeywell also produces the GyroDRM Dead Reckoning Module Evaluation Kit. This product is priced at $2995.00. The GyroDRM uses a single axis gyroscope to reduce the sensitivity of the unit to transient magnetic disturbances in the environment. It produces self-contained position data when navigating in areas where GPS signals are difficult to receive. This kit includes a GPS receiver and altimeter. This module also includes data logging memory with 32KB storage capability. Log files can be downloaded to a computer and analyzed using a spreadsheet program. The evaluation kit also includes test software, a re-chargeable Li-Ion battery, charger, and is supplied in a housing with a belt clip.
2.3 Existing Patents

The ability to determine the track of an individual using Dead Reckoning methods is described in several patents. A patent that is referenced by many of Honeywell's Dead Reckoning modules is "Dead Reckoning navigational system using accelerometer to measure foot impacts", number 5,583,776. This invention incorporates the use of Dead Reckoning functions with GPS position information, which provides the user with an autonomous navigation capability. The system integrates GPS data, DR sensors, and digital maps into a self-contained navigation instrument. This system combines a digital electronic compass with a silicon pedometer and a barometric altimeter to generate the Dead Reckoning system. The information gathered from the sensors is used in conjunction with GPS and digital electronic maps. Individual positions can be monitored by a central coordinating facility through a built-in radio frequency transponder.

Another patent "Portable navigation device with integrated GPS and Dead Reckoning capabilities", number 6,850,844, presents a device for portable navigation with positioning functionality. This device includes a GPS receiver and a Dead Reckoning component consisting of a rate gyroscope, pedometer and/or accelerometer. The components are adapted to communicate to the memory and processor.

2.4 Existing Literature

In the paper Design and Implementation of the Precision Personnel Locator Digital Transmitter System by Hauke C. Dampfling, a Precision
Personnel Locator is developed for the tracking and locating of first responders inside of buildings. This system consists of a wearable, battery-powered device that can transmit a signal that will relay information to a Base Station for location processing and display. This project implements a detailed communication platform that controls the transmission of information from the device. This allows support of up to 100 devices transmitting every second. The Locators transmit a multi-carrier "ranging signal" waveform that is received by a Base Station.

Another paper titled, A Helmet-Mounted Pedestrian Dead Reckoning System, by Stéphane Beauregard, develops a tracking system in which the motion sensors are mounted on a helmet. This placement is chosen because of the GPS antenna, which needs a clear view of the sky. A combined approach of Pedestrian Dead Reckoning (PDR) and GPS positioning is followed in this paper. When outdoors, the GPS positioning is used to calibrate and validate the PDR technology that is used. Pedestrian Dead Reckoning is the estimation of a step length and a course over ground. One disadvantage is that PDR systems are not transferable between users since step models are configured with a particular individual's walking pattern. For the step model, the acceleration magnitude signal is calculated from the three orthogonal accelerometer signals. Heading is derived from the motion sensor's yaw output. In this paper, the conclusions are that GPS position is inadequate for urban and "tactical" personal/personnel positioning and methods such as PDR are required.
3.0 Project Requirements

The device developed in this project is to consist of a combination of Dead Reckoning (DR) components and a GPS positioning component. The device, hereby referred to as Tracker, is to be used to determine the location of an individual wearing the Tracker whether the individual is indoors or outdoors. This is accomplished using a single device that dynamically switches between GPS and Dead Reckoning modes. An initial position of the Tracker is determined from obtaining a GPS signal. The Tracker then continues to obtain information from the GPS component as long as a signal is available. When the GPS signals are lost, the Tracker switches over to the use of DR components. The Tracker sends either its GPS or DR raw data to a PC for position plotting on a map.

The Concurrent Real-Time Positioning Console (CRTPC) is a PC program that takes in the raw data from the Tracker. The CRTPC runs the data through an algorithm to convert the raw position data to data that can be used for plotting on a map. The last GPS position data is used as the initial position in DR mode to which all subsequent positions are calculated. The entire DRS will calculate the distance that is traveled with an accuracy of 25% and the heading with an accuracy of 10%.

4.0 Design of Algorithm

Very little processing is done on the Tracker itself. Most of the position calculations are done on the much faster PC.
The whole DRS runs using the concept of operating modes. It has two operating modes: GPS and DR. For the most part, the code that is ran in each mode on both the Tracker and the CRTPC are mutually exclusive. This allows for more optimizations than might otherwise be possible for a combined GPS and DR tracking system.

4.1 Tracker Algorithm

The following describes the Tracker's modes of operation.

4.1.1 GPS Mode

The data Statement sent from the GPS component is directly ready for plotting. A valid GPS Statement contains a timestamp, latitude, longitude, heading, velocity, and other data about the position of the Tracker. Only some of the data is relevant for our project. The only processing tasks for the Tracker in GPS mode is to gather only the items of interest from the GPS Statement. Items from the digital GPS Statement that are not needed are thrown away. The items of interest are transferred to the CRTPC for plotting on a map. LEDs are lit to indicate that the Tracker is operating in GPS mode. If the Statement from the GPS component indicates loss of satellite tracking, the Tracker will switch to DR mode.
4.1.2 DR Mode

The data sent from the DR components are voltages corresponding to acceleration felt by the accelerometer and rotation felt by the gyroscope. While operating in DR mode, the Tracker checks the absolute value of these raw voltage values to ensure they are within ranges that indicate proper operation of the DR components. If the DR component is faltering, the Tracker would disallow any bad readings to be transferred to the CRTPC.

While in DR mode, the Tracker checks the status of the GPS Statement. If the Tracker finds that GPS satellite tracking is in good working order, it switches to GPS mode. Otherwise, the Tracker stays in DR mode. LEDs are lit on the Tracker to indicate that it is operating in DR mode.

The Tracker averages thirty readings from the DR components together and then sends the results to the CRTPC. This is done to reduce the bandwidth needed to facilitate communication between the Tracker and the CRTPC.

4.2 CRTPC Algorithm

The algorithms operating on the CRTPC are divided up for easy modification, maintenance, and readability. The following describes the CRTPC modes of operation.

4.2.1 GPS Mode

There is only one GPS specific algorithm. It involves a simple conversion of latitude/longitude coordinates. Only one small calculation is needed because
the data from the GPS component already contain the position data needed for plotting on a map. The DR algorithms are much more complex. They are divided up into an algorithm for the accelerometer readings, an algorithm for the gyroscope readings, and another for plotting on the map.

4.2.2 DR Mode

When in DR mode, the raw voltage data sent to the CRTPC is stored in an array. After receiving 200 readings from the Tracker, the CRTPC calls both the accelerometer and gyroscope algorithms. Both of these algorithms are very similar. They will be described together.

The voltage readings from the DR components are represented to three decimal places when they are sent to the CRTPC. However, the readings are not sent with a decimal point. Sending a decimal point is wasteful of precious bandwidth. So, the voltages are divided by 1000 in order to introduce the decimal point back into its correct position.

The voltages are always positive values. The DR components have a zero point of about 1.5V for the accelerometer and 1.6V for the gyroscope. (These values were experimentally determined.) This means that a negative acceleration would actually be represented with a positive voltage. This is counterintuitive. The zero acceleration and rotation points are subtracted from the voltages in order to make negative acceleration actually be represented by a negative voltage value. This means, for example, that the same magnitude of acceleration in the positive direction as in the negative direction will be
represented by the same positive and negative voltage value, respectfully. The discussion here is a bit over-simplified, but will suffice for the basis of this report.

Next, the voltage values are divided by a constant. The constant is defined in the data sheets for the DR components. For the accelerometer, this constant represents the conversion of voltage per force of gravity to forces of gravity. Similarly for the gyroscope, this constant represents the conversion of voltage per degree of rotation per second to degree of rotation per second. With the completion of this operation, the rest of the algorithms will be dealing with values in physical units instead of voltage units.

Thresholds are used to eliminate erroneous large spikes in the readings which tend to creep into electrical circuits.

A low-pass Butterworth filter of order 10, and cutoff frequency of 7 Hz is used to smooth the readings into a form which yields results that are easier to use to calculate positions.

An offset is calculated and subtracted from the readings in order to eliminate the constant force of gravity from the accelerometer readings. Gyro drift is subtracted from the gyroscope readings in the same manner. This eliminates the effect of the forces of nature that tend to make readings slightly erroneous.

When walking around with the Tracker, the acceleration and rotation measured appear to be almost at random. It is the slight patterned characteristics of the readings that the above steps try to bring out. However, when standing still, the algorithm performs an additional step. Very small
readings that occur over a long period are deduced to occur only when standing still. Therefore, those readings are reduced to zero to reflect the fact that no acceleration is occurring. This prevents any slight drift in position which may occur while standing still.

As a final condition to getting the readings conditioned to start producing real position data, the accelerometer readings are converted from forces of gravity to m/s² by multiplying the readings by 9.8 m/s².

For the acceleration readings, the acceleration is integrated to find speed (m/s). Speed is further integrated to find distance (m). Rotation rate (degrees/sec) readings from the gyroscope are integrated to find total rotation.

Now the DR readings have been converted into a form for plotting on a map. The direction of movement is remembered over time via a stored degree value from true North. This stored heading is added to the total rotation found from the gyroscope to find a new direction of movement. The cosine and sine of the heading is applied to the acceleration, speed, and distance. This is done to determine how much of the acceleration, speed, and distance to apply in the X and Y axes of the map.

As mentioned earlier, heading is remembered from the past and added to the heading change read over the current set of DR component readings. Other values remembered and applied in the same manner are X and Y positions on the map (latitude and longitude), speed in the North/South and East/West directions, and distance traveled from the time the Tracker entered DR mode.
A Google Map is used for plotting. This allows for operation of the device from anywhere in the world.

5.0 Design of DRS

The system designed employs the algorithm discussed above. The entire system, called Dead Reckoning System, or DRS, is made up of two pieces. The first piece is the "Tracker," the device worn by the person being tracked. The second piece is the "CRTPC," the PC program used to plot the position of the Tracker on the map. Consult Figure 5.0 for a block diagram of the DRS.
5.1 Tracker

The Tracker has a belt area in the rear of the device. This area allows the user to run his/her belt through the device for a firm attachment to the body. The waist area is the best place to wear the Tracker because the waist is close to the center of gravity of the human body. This acts to reduce unnecessary vibrations that would be introduced if the Tracker was worn on the ankle, or on a helmet.

Figure 5.1 displays the various components of the Tracker.

The DZ1611 acts as the main board to which all other components anchor themselves. It supplies power to the GPS and DR components through the use of a battery compartment on the underside. It also holds the MSP430 processor for implementing our Tracker algorithm.

Above the DZ1611 main board is the DR component board. It contains both the accelerometer and the gyroscope.

Above that is the GPS component board. It has a Lassen iQ GPS satellite signal receiver to which an antenna is connected.

The GPS component sends digital Statements to the MSP430's serial port B. The DR components send voltages to the MSP430’s Analog to Digital Converter. The output of the MSP430 will be put on the DZ1611’s Serial Port DB-9 connector for output to the CRTPC.

LEDs on the DZ1611 main board light up indicating which mode the device is operating in. GPS mode is indicated by the continuous lighting of LED #D1 and the blinking of LED #D2 once every second. Each time LED #D2 blinks, a new GPS message is sent to the CRTPC. DR mode operation is indicated by
Figure 5.1 Tracker
Figure 5.2.1 CRTPC "Data Processing Tool"
the lighting of LED #D3 and #D4. They blink once per second. Once per second, LED #D1 will also blink for a split second indicating that the Tracker is checking the GPS component for a good GPS signal.

5.2 CRTPC

The Concurrent Real-Time Positioning Console (CRTPC) program is used to process the GPS and DR messages that are received by the Tracker. When the user selects the Tracker that will be monitored and then presses the Start button, the CRTPC begins scanning the serial port for position data messages. The program uses the length of the position data message to determine if the message represents DR position data or GPS position data.

When the CRTPC detects a message that contains GPS position data, the program immediately begins processing the data. The latitude and longitude data is converted from "degrees minutes.decimal" notation to "decimal fraction notation." For example, 2327.500 E is converted to 23.45833° E. The speed is converted from kilometers/hour to meters/sec. The heading of the Tracker is sent in degrees from true North. This means if the Tracker is heading East, the GPS message would contain a heading of 90°. The latitude, longitude and speed of the Tracker are displayed on the CRTPC "Data Processing Tool" in the GPS section. During this time, the DR section is dimmed to indicate this mode is inactive. Figure 5.2.1 shows the CRTPC "Data Processing Tool."

When in DR mode, the mapping-axis position values are stored in Universal Transverse Mercator (UTM) coordinates, which are made up of Easting and
Northing coordinate pairs that correspond to a one square meter location. Since distance is measured in meters, UTM easily follows as the mapping unit of choice for the internals of the mapping algorithm. However, many people do not understand these coordinates. So the UTM position coordinates of the Tracker are converted to their equivalent latitude and longitude representation for plotting on the map.

When the Tracker switches from GPS to DR mode, the last GPS latitude and longitude values must be converted to UTM coordinates. This is so that the distance calculated in DR mode can be added to the UTM coordinates in order to keep a record of movement of the Tracker.

When a message contains DR position data the CRTPC program will scan the serial port for 200 consecutive scans before further processing the data. After that, the CRTPC will run through the accelerometer and gyroscope algorithms as documented in Section 4.2.2. The latitude, longitude, and directional speed of the Tracker are displayed on the CRTPC "Data Processing Tool." They are displayed in the DR section of the tracker. The GPS section is dimmed to indicate this mode is inactive.

The latitude and longitude of the Tracker is written to MappingData.xml, along with the mode of the Tracker. DeviceMap.html uses Google Maps API to embed a Google Maps into the web page. DeviceMap.html then reads MappingData.xml and parses the Tracker mode, latitude, and longitude values from the file.

If the Tracker is operating in GPS mode, a green icon and line follow the
Figure 5.2.2 DRS operating in GPS mode

Figure 5.2.3 DRS operating in DR Mode
movement of the Tracker. Figure 5.2.2 shows the DRS operating in GPS mode. If the Tracker is operating in DR mode, a red icon and line follow the movement of the Tracker. Figure 5.2.3 shows the DRS operating in DR mode. The color and position of the line is remembered over time so that the user can see the history of movement of the Tracker, when the Tracker operated in DR mode, and when it operated in GPS mode.

When the Stop button is pressed, all processing of data will terminate. The user can then press the "Export to Excel" button to write all latitude, longitude, directional speed, and distance values recorded during processing to an Excel file. This file also contains a timestamp for each entry. The user can also reset the CRTPC data tool by pressing the Reset button. This clears the CRTPC data tool so that another tracking session can be started.

6.0 Testing

Several test cases were developed for testing the algorithms of the Dead Reckoning System. Each test run satisfied one or more test cases. Each test case is detailed below. Also detailed are test runs that satisfied these test cases.

6.1 Straight-line Test

The object of this test case is to walk in a straight line for a measured physical distance and verify that the calculated speed and distance is within requirements. The requirement verified using this test is that the DRS can calculate the distance traveled with an accuracy of 25%. The distance tested in
the test run was 10 meters. After walking 10 meters, the movement was
stopped. Figure 6.1 shows the calculated distance to be about 9 meters. The
red "Travel Distance" shows the calculated distance traveled in the direction of
movement.

6.2 Turning Test

The object of this test case is to turn around and verify that when the user
turns, the Tracker can specify a new heading within 10% of the actual turn. The
rotation tested in this test case is a turn of 180° and then another turn of 180° for
a total rotation of 360°. This test run was combined with another test run in order
to test the test cases of Section 6.2 and 6.3 at the same time. Please see
Section 6.3 for a discussion of the test run and the results.

6.3 Straight-line, Turn, and then Straight-line Test

The object of this test case is to walk in a straight line for a measured
physical distance, turn a certain amount, and then walk in a straight line for the
same measured distance. The test run included walking in a straight line for ten
meters, turning around 180°, and then walking ten meters back to the original
position. This test verifies that the angle of rotation is within 10% of actual turn
and that the distance traveled is within 25% of the starting point.

Figure 6.3.1 shows the accelerometer readings and the calculated speed
and distance traveled. The red lines represent the data in the direction of
movement. The green lines represent the data in the up/down (vertical) axis.
Figure 6.1 Straight-line Test
Figure 6.3.1 Straight-line, Turn, and then Straight-line Test

Figure 6.3.2 Straight-line, Turn, and then Straight-line Test
The blue lines represent the data in the left/right direction. The first graph of Figure 6.3.1 shows the acceleration measured during this test. The second graph shows the speed found from the acceleration. As can be seen, the primary speed is in the direction of movement. The third graph shows the distance traveled. Most of the distance traveled is in the direction of movement. The initial distance traveled is a little less than ten meters. The secondary distance traveled does not go back to zero as expected. This is attributable to the Tracker device not properly being oriented in the direction of movement. It appears from the graph of speed that the X axis of the accelerometer received more of the acceleration in the direction of movement than did the Z axis. These bad results are not reproducible, so it appears the bad result is an error that is attributable to experimental error.

Figure 6.3.2 shows the gyroscope readings measured from this test. The first graph in Figure 6.3.2 shows the voltage readings from the gyroscope. The data in green shows two turns in the y-axis. The second graph shows the gyroscope data in degrees. The first turn is calculated to be about 177° and the second turn is calculated to be about 355°. These results are within the 10% accuracy requirement.

6.4 GPS Data Transmission Testing

The object of this test case is to verify that, when walking outside with the Tracker on, the position displayed by the CRTPC corresponds to the actual position of the Tracker. This position should be displayed with a green icon on
the map. Verify also that the CRTPC shows the Tracker is operating in GPS mode by displaying position and speed data in the GPS section of the "Data Processing Tool." This test run includes straight-line tests and turning tests. This tests includes an in depth test of the Google Maps display. Figure 6.4 shows the results of this test. Walking outside in the right side of my backyard, you can see that the position tracking is pretty accurate. This GPS position and speed data is displayed on the "Data Processing Tool" and the icon representing the current Tracker position is green. Also notice that there is a letter "G" inside the icon and that the history of movement is a green line.

6.5 Mode Transition Testing

The object of this test case is to verify that the Tracker switches to DR mode when GPS signals are lost. Verify also that the DR speed and position show up in the DR section of the "Data Processing Tool" and that the icon and historical track on the map turn to a red color. Finally, verify that the CRTPC still shows the GPS historical movement track and the last GPS position and speed data in the dimmed GPS section of the "Data Processing Tool." An initial GPS signal is required to determine the location of the Tracker. Then the Tracker was moved inside the building where then, the GPS signal was lost. As you can see in Figure 6.5, the Tracker switches to DR mode (indicated by the change of the historical track from green to red). Also, the speed and position data are being displayed in the DR section. The last reading before the switch from GPS to DR mode is displayed in the dimmed out GPS section.
Figure 6.4 GPS Mode Test
Figure 6.5 DR Mode Test
7.0 Innovation

This product is innovative in that it offers real-time position calculation. All other products that are currently available on the market offer data-logging capabilities only.

Wearing the Tracker on your waist minimizes extraneous vibrations by keeping the Tracker close to the body's center of gravity. Most products that are currently on the market suggest that the user wear the device on the ankle or even a helmet.

We also provide a longer battery life through use of Low Power Modes and minimal processing on the MSP430 microprocessor.

DRS is extremely cheap in price. Most devices researched were being sold for well above $1000. We can sell ours for $400.

8.0 Cost

All of the components used in the development of this prototype were provided by UAH and the Redstone Technical Test Center (RTTC). The total cost breakdown for this project is as follows:

- One SoftBaugh DZ1611/1612 Zigbee board - $169.00
- One IMU Five Degrees of Freedom, Accelerometer/Gyroscope board - $109.95
- One Lassen iQ Evaluation kit with USB, GPS board - $116.70
- Assorted batteries - $10.00
- Total - $390.65
9.0 Manufacturability and Sustainability

Multiple manufacturing processes for separate modules would exist for this product. This will create a higher risk of failure in any one of the processes during the entire manufacturing process. Reducing the number of modules and parts that are used in the design can lower this failure rate. We have reduced the number of modules by removing the need for a compass and incorporating its operation into our algorithms. Future plans of designing a custom PCB that contains the MSP430, battery compartment, belt area, and anchor positions for the GPS and DR components would remove the need of the DZ1611 from our design. This would then reduce the number of modules associated with our design and also the overall size of the Tracker itself. This would in turn reduce the rate of machine soldering errors and reduce the cost of manufacture.

10.0 Conclusions and Recommendations

Based on our results, the Dead Reckoning System is reasonably accurate in monitoring an individual wearing the Tracker. The Tracker acquires GPS signals and accurately displays the location of the Tracker on the Google Map. The speed and direction of the Tracker are also correctly displayed on the data tool. When GPS signals are lost, the Tracker switches over to reading from the Dead Reckoning components. The majority of the tests that we performed with the Dead Reckoning components met the 25% accuracy requirement for distance and the 10% accuracy requirement for heading.
There are several recommendations that we would make based on our experiences with this project. We would like to implement wireless communication between the Tracker and the CRTPC. This would allow more usability for the DRS.

Another recommendation would be to implement a multi-threaded CRTPC. One thread would communicate with the Tracker and the other thread would process the readings. This would improve accuracy for better tracking because more time would be spent listening to the Tracker as it sends data. As a result, more bandwidth would become available for communication, so averaging would not have to be done on the Tracker. Averaging acts to reduce the accuracy of position calculations.

The final recommendation would be to store the map locally on the PC’s hard drive to improve the access time of the map pictures. Internet is slow, unreliable, and not always available. If the CRTPC had a cache of mapping pictures, it would not only improve processing time, but increase the rugged ability of DRS by reducing the need for the internet.

The primary purpose of this project is to develop a tracking algorithm. Testing results of the algorithm show excellent results. While the development of the algorithm was a complex task, implementation of the algorithm was even more complex. The algorithm had to modified slightly to produce real-time monitoring of the Tracker. Timing constraints turned out to be the biggest issue. Speed requirements of the PC were very high so that the CRTPC could keep up
with the Tracker. Never fail to take into account the environment in which you are developing!

### 11.0 Acknowledgements

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Appendix A: References


Appendix B: Tracker Code

C++

If you desire to consult the Tracker Code,
please contact Betty Cole
in the Honors Program Office
at 824-6450 or coleb@email.uah.edu
for permission to do so.
Appendix C: CRTPC Code

MATLAB R2007a

If you desire to consult the MATLAB Code,

please contact Betty Cole

in the Honors Program Office

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