Final Report

Application of DGPS for Collision Avoidance in Intelligent Transportation Systems In a Wireless Environment

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Submitted to

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Executive Summary

This project evaluated the application of Global Positing System (GPS) technology in collision avoidance. This system tested in this research utilized both GPS and wireless communications.

The Global Positioning System (GPS) is a satellite based radio-navigation system with satellites orbiting the Earth, and transmitting radio signals to ground receivers (i.e. GPS devices). Based on measurements of the amount of time that the radio signals travel from a satellite to a receiver, GPS receivers calculate the distance and determine with great accuracy the location of their antennae in terms of longitude, latitude, and altitude. GPS can be used in various areas such as air, land, and sea navigation, mapping, surveying and other applications where precise positioning is required.

A relatively large number of vehicles is already equipped with GPS devices whose accuracy is about 20 meters. Position accuracies obtained with GPS can be as good as 1 cm in real-time, however the cost of such devices is still very expensive to be incorporated as a standard item in vehicles.

The system implemented in this research consists of a GPS device on a vehicle that is capable of receiving differential processing signals. Using wireless communications, the vehicle radio sends the vehicle's position to a central traffic server, which evaluates potential collision scenarios with another simulated vehicle. If a collision is imminent, the server radios back a cautionary message to the roving vehicle.

While GPS technology is superior to other technologies, it also has its own limitation. Namely, the technology works only in situations where it receives signals from all other objects in its vicinity. This means that other objects in the surrounding area have to either have a fixed and known location, or be equipped with GPS devices and wireless communications.

The wireless communication routines for communicating with the server and receiving caution messages from the server were tested extensively with extremely fast response times.

This project proves the viability of using GPS technology for collision detection avoidance. As the majority of the components used for this research are expected to be standard items in vehicles, the main cost and challenge will be the computational infrastructure needed to detect collisions and warn vehicles in an extremely short period of time. For this reason, more research is needed to evaluate whether collision avoidance calculations should be implemented on a central traffic server or within each vehicle, where vehicle computers only evaluate traffic in each vehicle's vicinity.

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Table of Contents

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I. Abstract:

Traffic accidents that occur as a direct results of collision represents the majority of accidents occurring on your highways and streets, and lead to hundreds of thousands of fatalities and injury to people and destruction to property. The aim of this project is to reduce the number of collisions through the application of the Global Positing System (GPS) and wireless communications. Even a small reduction in the number of these incidents yields very large savings and improvement to the quality of life.

In this project, the researchers developed and implemented a study where GPS technology was used in tracking a single vehicle and relaying its information to a central server. Using another simulated vehicle, the server evaluated collision scenarios and sent cautionary messages to the roving vehicle if a collision is expected.

II. Collision Avoidance Technologies

Several technologies exist for collision detection and avoidance. They differ in their cost, size, response time, reliability, and effective operation range. Ultrasonic technologies rely on high frequency devices. They have a low implementation cost, small size, and have a fast response time. They are however not reliable under some conditions, and their range is only a few feet.

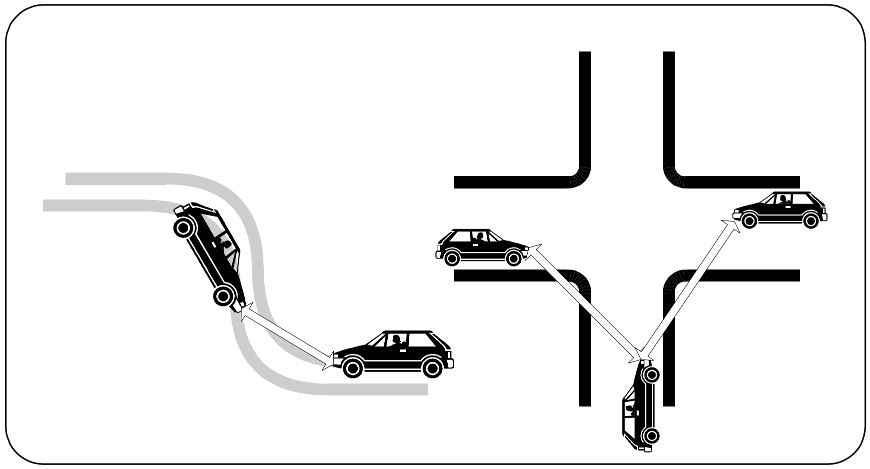
Infrared technologies have been used for a while. They have a very small implementation cost and are small in size. However, they exhibit a high response time, are not very reliable and their range is also very short.

Radar technologies are perhaps the most effective for collision detection. Improvements have led to size reductions and high reliability. However, their cost is relatively high.

Vision technologies have also been used for collision detection. However, their cost is extremely high due to heavy computational requirements. They also suffer from low reliability in some lighting conditions.

GPS technologies have not been used for collision detection. These technologies offer a multitude of benefits and their costs have been continuously decreasing. The major benefits of using GPS is that these technologies are not dependent on line-of-sight issues (to other vehicles) which is one of the major limitations of all the technologies listed above. This is explained in the diagram below when two opposing vehicles are traveling on a divided highway. GPS technology coupled with Geographic Information Systems (GIS) can determine that while both vehicles are on a theoretical collision course, a collision cannot occur due to the existence of a median or a barrier on this divided highway.

While GPS technology is superior to other technologies, it also has its own limitation. Namely, the technology works only in situations where it receives signals from all other objects in its vicinity. This means that other objects in the surrounding area have to either have a fixed and known location, or be equipped with GPS devices and wireless communications.



III. The Gl

Figure 1

Global Positioning System (GPS) is a satellite based radio-navigation system. There are 24 GPS satellites orbiting the Earth and transmitting radio signals. Based on measurements of the amount of time that the radio signals travel from a satellite to a receiver, GPS receivers calculate the distance and determine the locations in terms of longitude, latitude, and altitude, with great accuracy. GPS was created, and is controlled by the U.S. Department of Defense (DOD) for military purpose, but is available to civilian users worldwide free of charge.

GPS can be used in various areas such as air, land, and sea navigation, mapping, surveying and other applications where precise positioning is required. The system inherently has no limitation in speed or altitude, but U.S. DOD requires that commercial receivers be limited to operate below about 900 knots and 60,000 feet (18,000 meters).

1) GPS Satellite Signals

GPS satellites transmit two carrier signals, L1 and L2. The L1 frequency carries the P-Code (Precise Code), C/A (Coarse Acquisition) Code, and navigation message. The L2 frequency carries a P-Code and navigation message and is used to measure the ionospheric delay by PPS equipped receivers.

The Navigation Message also modulates the L1-C/A code signal. The Navigation Message consists of data bits that describe the GPS satellite orbits, clock corrections, and other system parameters (Dana, 1996).

2) GPS Receivers

GPS receivers can be categorized broadly into three types based on accuracy: C/A code, carrier phase and dual frequency receivers. Each of the three types offers different levels of accuracy, and the price of the receiver is dependent on its accuracy.

C/A code receivers typically provide 1 ~ 5 meter accuracy with differential correction, with an occupation time of 1 second. Longer occupation time (up to 3 minutes) will provide accuracy consistently within 1 ~ 3 meter and can be reduced to 30 centimeter.

Carrier phase receivers typically provide 10 ~ 30 cm accuracy with differential correction. Distance to satellites from the receiver is determined by counting the number of waves that carry the C/A code signal (referred to as ambiguity resolution). This method is much more accurate but requires a substantially higher occupation time to attain 10 ~ 30 cm accuracy.

Dual-frequency receivers are capable of providing sub-centimeter accuracy with differential correction. Dual-frequency receivers receive signals from the satellites on two frequencies simultaneously.

3) Basic Concept of GPS

Using GPS satellites as reference points, a GPS receiver determines its location based on the distances between the receiver and GPS satellites. The satellites are used as reference points because their orbital motion is constantly monitored by ground control stations so that their instantaneous positions are always know with great precision (Hurn, 1993).

The distance between a receiver and a satellite is calculated using a simple equation of Distance = Speed x Time, where *Speed* is the speed of the signal which is transmitting at the speed of light (186,000 mile/sec). *Time* is the time for the signal travels from the satellite to the receiver. Time can be calculated by measuring the departure time of the signal at the satellite and the arrival time at the receiver. (Hurn, 1989).

For example, a receiver determines that the distance to a satellite, S1, is 23,000 kilometers. This one measurement indicates that the receiver is somewhere on the surface of an imaginary sphere that is centered on satellite S1 with a radius of 23,000 kilometers. If the receiver measures that its distance to a second satellite, S2, is 26,000 kilometers, then it narrows down where it could be in space. The only places that are both 23,000 km from the satellite S1 and 26,000 km from the satellite S2 are where those two imaginary spheres intersect. That intersection is a circle of points. A third measurement adds a third sphere, which will intersect the circle formed by the other two. The intersection occurs at two points and the receiver has narrowed down its position to two points with three measurements.

A fourth measurement would go through one of these two points and pinpoint the position. However, it is not necessary to have a fourth measurement to decide the position because one of two points will be unreasonable, for example, thousands of kilometers from the surface of the earth.

However, a fourth measurement is needed for another reason. It helps the receiver to ensure that its clock is truly synchronized with the atomic clocks on board the satellites (Hurn, 1993). This is the reason that a minimum of four satellites are needed for accurate position determination.

4) GPS Position Accuracy and Error Sources

Accuracy of GPS is the degree of conformance between the estimated or measured position, time, and/or velocity of a GPS receiver and its true time, position, and/or velocity as compared with a constant standard. Radio navigation system accuracy is usually presented as a statistical measure of system error and is characterized as predicable, repeatable, and relative accuracy (*Fundamentals of GPS*, 1996).

The accuracy of GPS receiver is affected by errors caused by natural phenomena, mechanical failure of elements in the system, or intentional disturbance. The Selective Availability (SA) Error is intentionally introduced to the GPS signals and then is broadcast by the satellites. It effectively is a 30 meter range error that varies over time. This error, the largest contributor of overall errors in the system has been turned off permanently as of May 2000.

The Ionospheric Error is a function of the local time of day and latitude. It is largest in the tropics in the afternoon. Mathematical models have been introduced to reduce ionospheric errors.

The Troposhperic Error is a function of the weight of the atmosphere above the GPS antenna and is modeled using the atmospheric pressure. It is usually not a factor in position accuracy. GPS receivers can model this effect to a few centimeters knowing only the altitude.

The Orbit and Satellite Clock Error occurs because there are slight variations in the orbits of GPS satellites. Monitoring stations track this error and broadcast these corrections to the satellites. Because of the delay in sending these corrections, orbit errors exist. In addition to the satellite position, the atomic clocks drift off causing another error in time measurement and therefore in position.

The Multipath Error occurs when strong signals from satellites are not along the direct line of sight between the user's antenna and the satellite. GPS antennas can receive signals from anywhere above the horizon and some of these signals may have been strengthened due to reflections from other objects. When the direct signal from the satellite is not considered in the solution, range errors to the satellites occur leading to measurement errors. The GPS antenna location is therefore extremely important. Multipath is often the dominant error source in DGPS applications on mobile applications.

The Receiver Noise Error occurs as electronic devices emit electromagnetic energy, some at the GPS frequencies, which contributes a range error to the measurement. Newer GPS technology has been successful in reducing this error.

5) Differential Correction of GPS Positions

Differential GPS (DGPS) is a means of correcting for some system errors by using the errors observed at a known location to correct the readings of another receiver (rover). A reference receiver, or base station, computes corrections for each satellite signal. Most of the errors caused by the sources discussed earlier are eliminated by differential correction. Differential corrections may be used in real time or post-processed (Dana, 1996).

The most important consideration in DGPS is that the base station and rover have to be tracking the same satellites and taking data at the same time. For this reason, the base station and rover should be within 150-km limit. The quality of the corrections is a function of the distance between the base station and the rover.

Error	DGPS Cancellation
Selective Availability	Cancelled Completely
Ionosphere	Function of Distance to Base
Troposphere	Function of Distance to Base
Orbit & Satellite Clock	Cancelled Completely
Multipath	Does Not Cancel
Receiver Noise	Does Not Cancel

IV. Hardware Architecture

The hardware is comprised of two subsystems, a server subsystem, and a mobile (rover) subsystem. The server subsystem consists of a PC-based server connected to a radio. The rover consists of a differential GPS system receiver, GPS, a laptop, and a radio. The system architecture is shown in Figure 2.

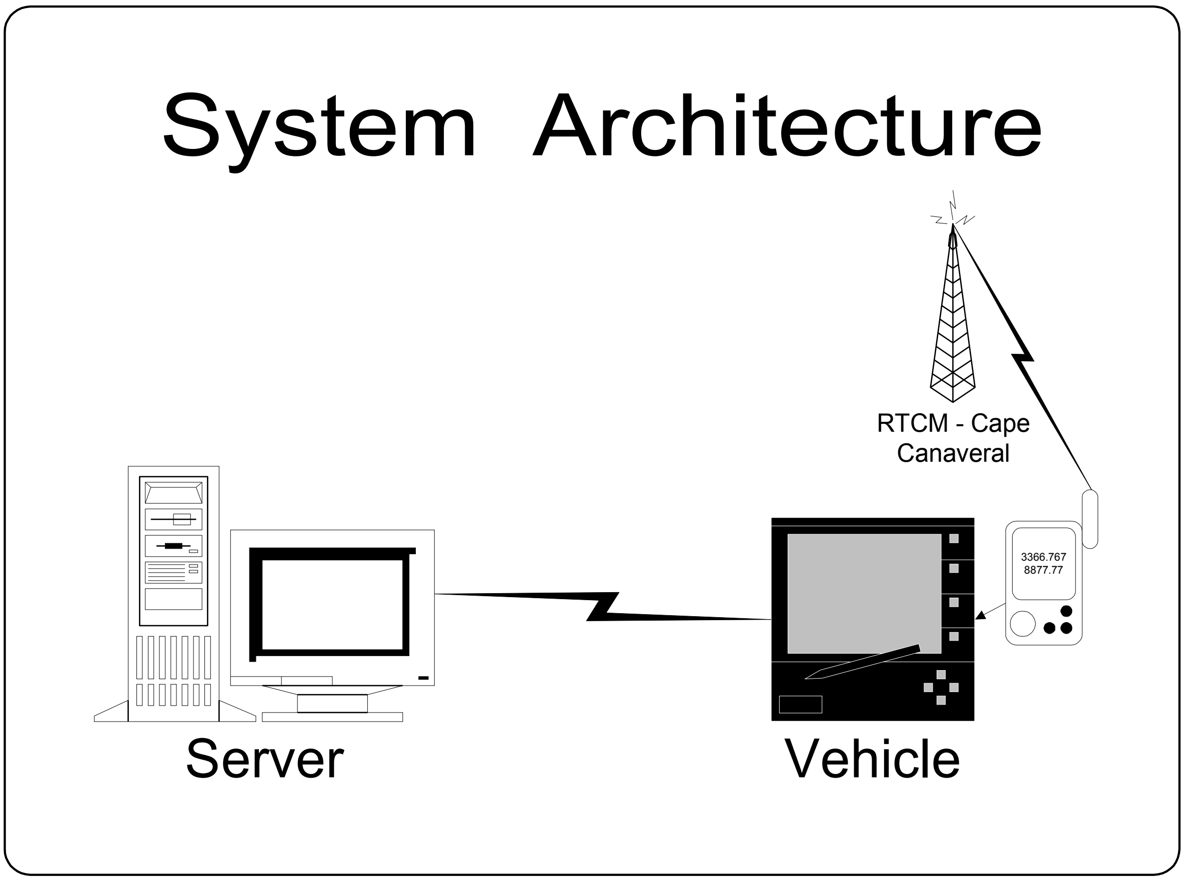


Figure 2

V. Software Architecture

The software applications are shown in Figure 3. The software consists of:

1) Server Software

This software receives position information from the rover and calculates potential collision scenarios with the simulated vehicle. The position of all vehicles is shown on the UCF campus aerial map. If a potential collision is detected, the vehicle is alerted through wireless communications.

2) Vehicle Software

This software receives the DGPS message and then sends it to the server. The position is formatted according to the $GPRMC sentence which is decoded as follows:

```
$GPRMC,221846,A,4916.45,N,12311.12,W,050.5,054.7,191199,020.3,E*68
```

221846	Time of fix 22:54:46 UTC
A	Navigation warning A = OK, V = warning
4916.45,N	Latitude 49 degrees 16.45 min North
12311.12,W	Longitude 123 degrees 11.12 min West
050.5	Speed over ground, Knots
054.7	Course Made Good, True
191194	Date of fix 19 November 1999
020.3,E	Magnetic variation 20.3 degrees East

The vehicle program broadcasts that location to the Traffic Server which will also decode and display "Caution" signals from the Traffic Server.

If the server software detects a potential collision, a message is broadcast to the rover (vehicle) with the speed and direction of the simulated vehicle.

VI. Collision Detection Algorithm

The collision detection algorithm works by calculating the intersection point of the two vectors representing two moving vehicles. Each vector is defined by a point And a direction. In this case, The GPS position of the vehicle (i.e. vehicle location), and the vehicle bearing (also from GPS input) define each vector.

After the intersection point is computed, and knowing the vehicles' speeds from GPS, the program calculates the distance from the potential collision point to each vehicle location. The program also calculates the braking distance required for each vehicle in its operational scenario. If the braking distance required approaches the distances above (within a specified tolerance value), the server then issues potential collision alerts to the vehicles in question transmitting an alert message, along with the direction and distance of the vehicle in question.

VII. Software Implementation

The software was implemented using Visual Basic and a host of other custom controls. The rover software is shown in Figure 4. Figure 5 shows a screen dump of the rover software when a potential collision is detected.

The server software screen is shown in Figure 6. Figure 7 shows an aerial photograph of part of the UCF campus where the system was tested. Figure 8 shows an enlarged section of Figure 7 with simulated vehicle tracks.

The software code for the server and rover packages is included in the Appendix.

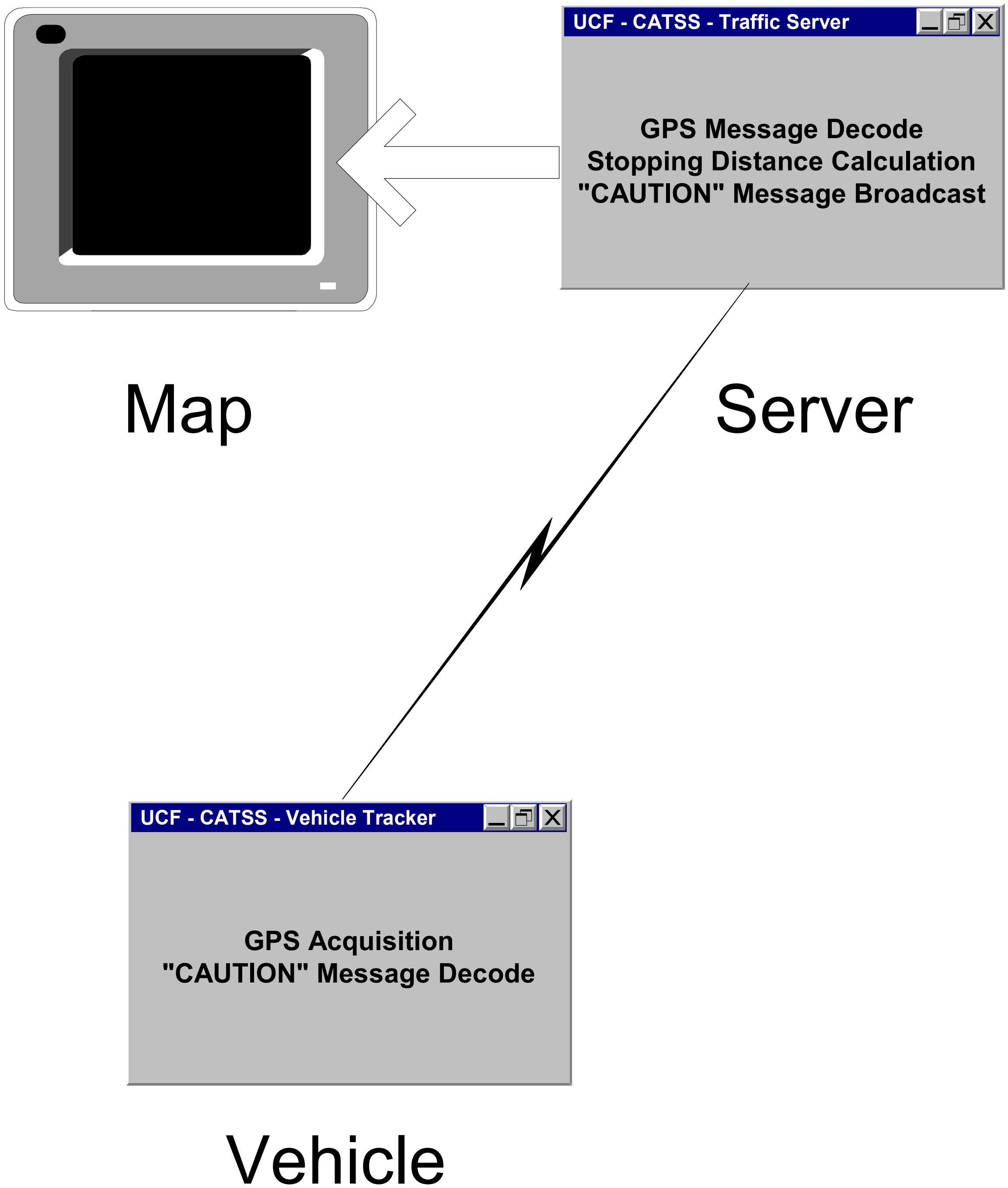

UCF - CATSS - Traffic Server
GPS Message Decode
Stopping Distance Calculation
"CAUTION" Message Broadcast
Map
Server
UCF - CATSS - Vehicle Tracker
GPS Acquisition
"CAUTION" Message Decode
Vehicle

Figure 3

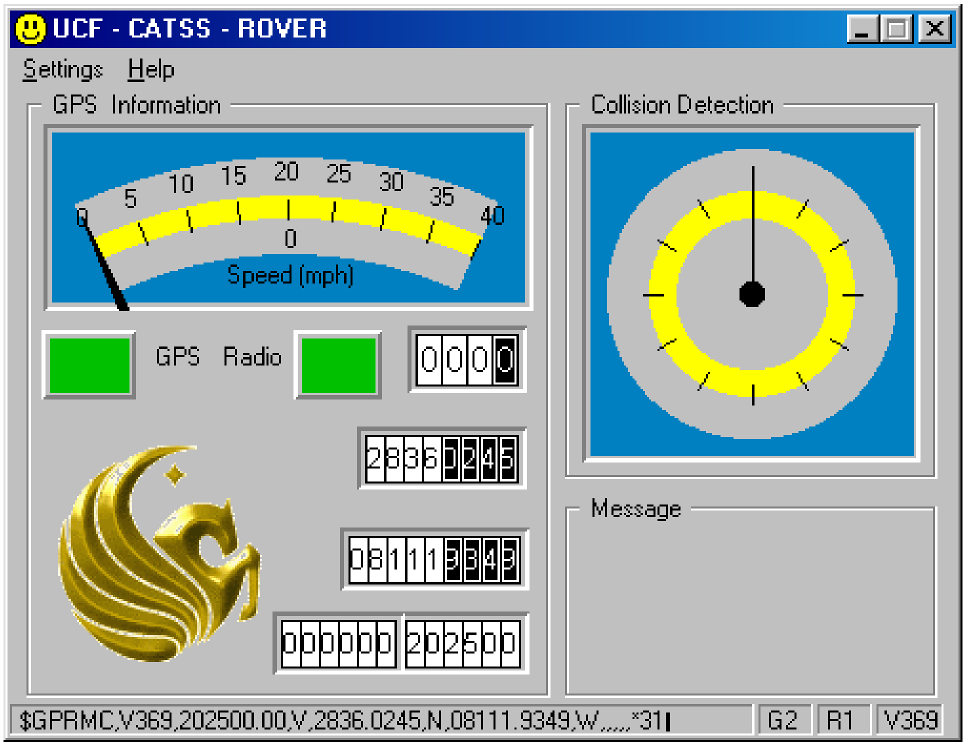


Figure 4

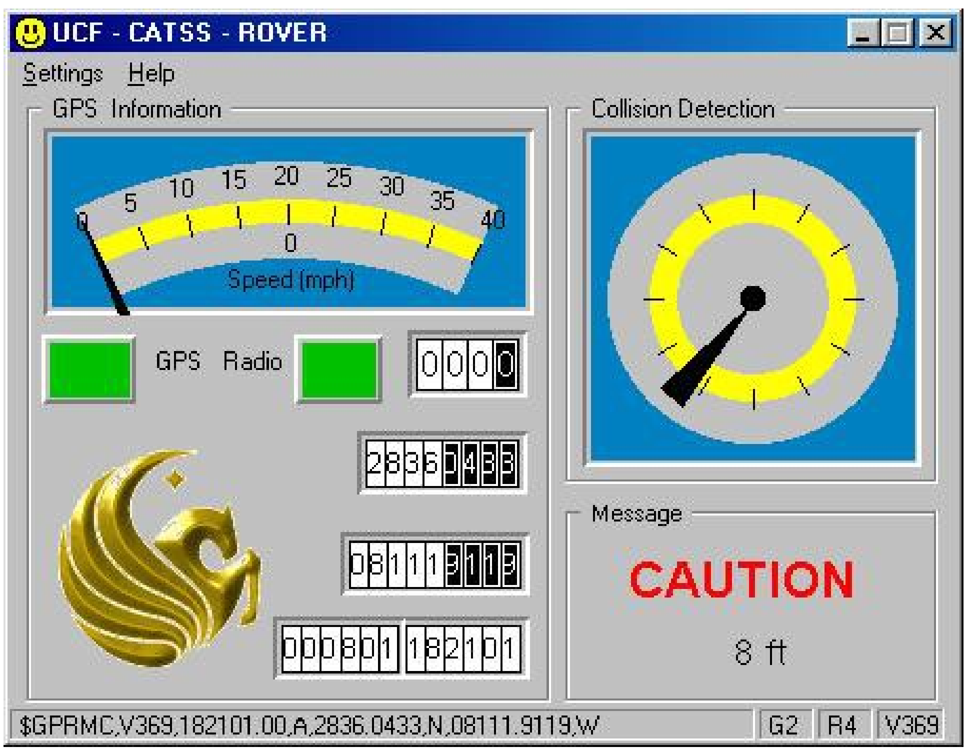


Figure 5

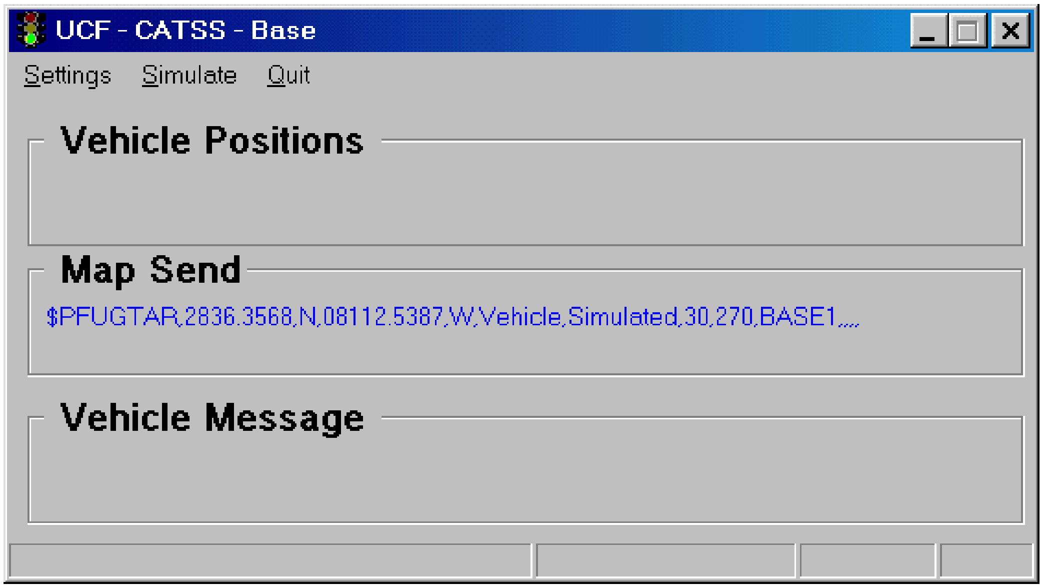

UCF - CATSS - Base
Settings
Simulate
Quit
Vehicle Positions
Map Send
$PFUGTAR,2836.3568,N,08112.5387,W,Vehicle,Simulated,30,270,BASE1,,,,
Vehicle Message

Figure 6

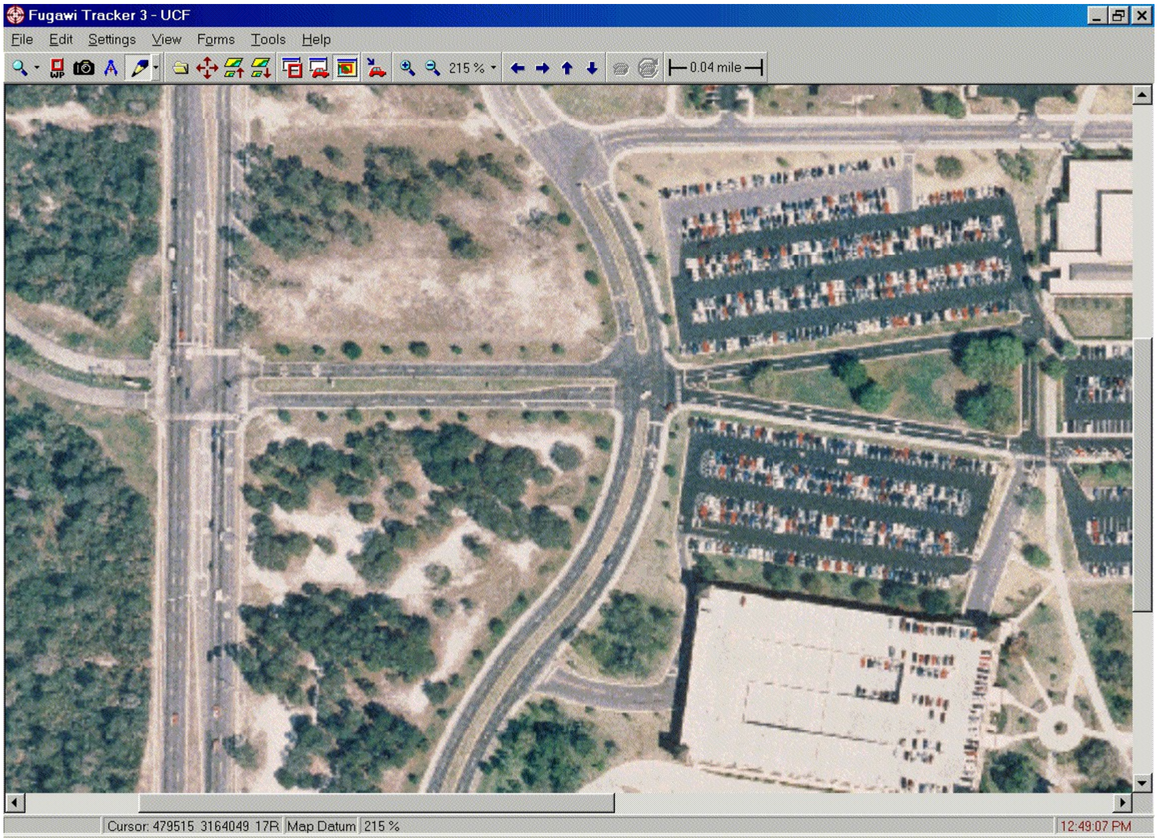


Figure 7

Figure 8

VII. System Testing

The wireless communication routines for communicating with the server and receiving caution messages from the server were tested extensively with extremely fast response times.

The entire system including map display and continuous vehicle tracking were tested on the UCF campus. The researchers evaluated the system using radios operating in the 900 Mhz. Frequency range. Figures 9 & 10 show a picture of the vehicle and system used in testing. Figure 11 shows a screen of the real-time tracking on the UCF campus using the vehicle above.

VII. Future Challenges

As mentioned earlier, this project was a limited study of the potential of GPS in Collision avoidance. The study was limited to a single vehicle in potential collision with a simulated vehicle

Future work will need to evaluate the scalability impacts of this work if several thousand vehicles are involved. In this case, several important issues need to be evaluated:

1) System Architecture:

Should evaluation be done on a Central Server or within each vehicle? This is an elusive problem as local computing in the vehicle may be more efficient, however, it will potentially increase the cost of the computational hardware needed. In this project, all processing was done on a central server.

2) System Response Time:

Collision Avoidance requires immediate and reliable feedback. Internet delays in the case of busy servers of a 2-3 seconds may not be of any consequence for business traffic, however, in collision detection, this could be the difference between life and death.

3) System Integration:

Under normal driving, any collision avoidance system will always flag several potential collisions until drivers slow down their vehicles by braking. If the tolerance margin for server notification of potential collisions is reduced, there may not be sufficient reaction time for the drivers to apply the brakes. In the case of a large tolerance, the server will notify the drivers of too may collision possibilities that will turn driving into a potential nightmare! The solution is in the future integration of this technology with other collision detection technologies, and in connecting these systems to vehicle braking and control systems. In this case, the cars can be programmed to execute evasive maneuvers on their own without operator intervention.

IX. Conclusion:

This project proves the viability of using GPS technology for collision detection avoidance. As the majority of the components used for this research are expected to be standard items in vehicles, the main cost and challenge will be attributed to the computational infrastructure needed to detect collisions and warn vehicles in an extremely short period of time. For this reason, more research is needed to evaluate whether collision avoidance calculations should be implemented on a central traffic server or within each vehicle, where vehicle computers only evaluate traffic in its vicinity.

Figure 9

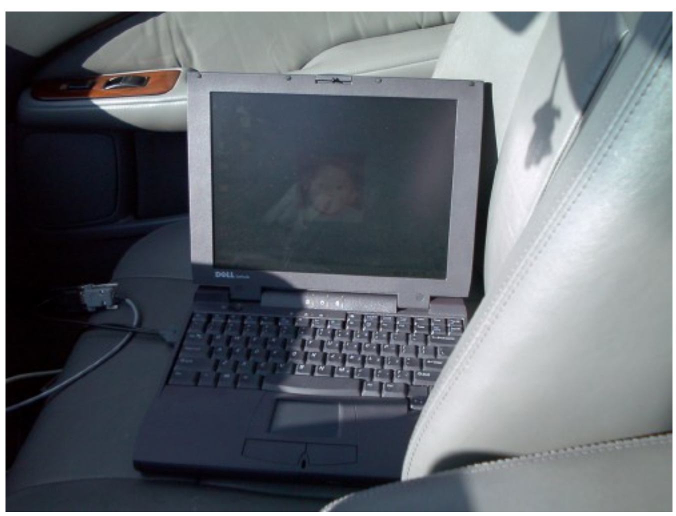


Figure 10


Fugawi Tracker 3 - UCF_Union3
File
Edit
Settings
View
Forms
Tools
Help
200 %
V369

Figure 11

X. References

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