Automated Map Follower

1. Introduction

The objective of this project is to design a system that allows a vehicle to drive autonomously from one destination to another. Car systems have evolved to include a number of functions which permit safer driving and allow drivers to also navigate destination routes a lot easier. One of the proposed developments to further ensure safety in the road would be to allow for driver-less vehicles which are better able to methodically assess driving conditions in order to quickly adapt to an adverse conditions in the surrounding environment. By replacing the human driver with a system that can autonomously drive the vehicle, it is likely that driving can be made safer for both commuters and pedestrians.

The project will design a scaled version of the prototype which will mirror the full functionality of the design. In order to deliver this finished product within the allotted time of 8 months, the team will complete the tasks of design selection and approval, testing and simulation, building of product and final testing to ensure the product performs as expected.

In developing a solution for an Autonomous Map follower, several engineering courses and skills covered by the engineering curriculum will be employed. A good knowledge of circuit analysis covered in Network Analysis lectures and labs will be essential in designing circuit schemes for achieving the desired system. Also, a working knowledge in micro computing will be required in utilizing processors which will be a core part of the design implementation. Other Engineering courses which will be applied include Signals Processing, Electronics, Energy Conversion, Programming, as well as the various lab classes. These courses will be essential in developing the design solution and implementing it with an actual prototype.

This project is an initiative of, and also sponsored by Chrysler LLC, the American car manufacturer. Chrysler is at the forefront of developing auto vehicles that will improve safety on the roads. The company has partnered with the Howard University Engineering department to provide students with real-world design experience by giving the students an opportunity to work on projects that are relevant to the current auto industry. Chrysler will be funding the project and will also serve as a resource to the students throughout the projects duration. A Chrysler employee will also serve as a mentor to the students.

2. Problem Definition

The problem we are faced with is to design a system that allows a vehicle to drive autonomously from a start location to a desired destination pre-determined by the vehicle operator which is based off a previously determined map. The development of this system has a focus on making certain that both safety and convenience are priorities when traveling. By taking human error out of the equation, the Autonomous Map Follower can provide less hazardous travel situations and lower accident occurrences. In the immediate future, a scaled prototype will be designed and created to test and replicate these desired results. The autonomous vehicle system, and prototype, will be able to do the following:

- Calculate a route approximately 1 minute after nput and automatically drive the route to a destination determined by the user
- Stop at said destination without any user input after the initial destination determination within 1% error margin

- Alert the user by way of sound or signal upon arrival at said destination within 3 seconds of arrival
- Allow the user to abort on-going destination navigation approximately 1 minute after notification

Additional requirements of the autonomous vehicle and prototype include:

- The user may be allowed to change their desired destination during the on-going navigation within 10 seconds of notification
- Automatically calculate and return to their departure location
- Stop at destinations along the original destination route without hampering/interfering with the original final destination
- Turn off remotely

The following constraints will have to be taken into consideration when developing the system prototype:

- System should be developed within the 8 month time period allotted for the project
- Cost of the entire system must be less than $1500

The automated map following vehicle and prototype must adhere to the following safety standards:

- The IEEE 802.11 standard for information technology, telecommunications and information exchange between systems (local and metropolitan area networks)
- The FCC standard CFR 47 part 15 in regards to unlicensed transmission
- IEC 61108-1 Standard for Global positioning system (GPS) Receiver equipment

Road safety has been a paramount issue since the invention of automobiles. It is generally believed that by reducing the driving role of humans with more automated systems, there will be increased safety in driving automobiles.. Such technology is necessary in order to increase the safety of commuters on the roads. By building an effective and accurate machine, road conditions will be continually assessed by the system to ensure that safety measures are constantly employed or adhered to while driving.

3. **Current Status of Art**

In reviewing the various technologies which could be used in designing the system, the focus was on identifying technologies that enable location mapping of vehicles. A processor will be used in controlling the steering and accelerator of the vehicle, however the processor must be able to determine the car's correct position in order to issue the right instruction to turn right or left toward s the intended destination. As such, a reliable means of pin-pointing the cars actual position is critical to this project. Current technologies which are available and have been successfully used in location mapping include the following:

GPS

Systems using GPS have been employed in various location mapping devices. It is used in a lot of vehicles today in determining location on a map. The GPS system has also been successfully utilized in developing autonomous vehicles as displayed in the DARPA competition. The Urban Challenge sponsored by the U.S. Defense Advanced Research Projects Agency (DARPA) is a

competition which has produced vehicles utilizing a robot system navigating a determined path using GPS coordinates. A key advantage of utilizing the GPS system is that it is a proven system that can be employed at low costs. Integrating the GPS with a controller for manipulating the cars driving components will serve the purpose of making the car system autonomous. However, one requirement of utilizing this technology is that the system will have to be integrated within the vehicle components and as such cannot be an add-on system. Another weakness is that error of margin of GPS systems which typically range between 3-5 feet. This means that the vehicle's position cannot be exactly determined and is thus prone to error. The weakness of this design would be that the map follower could not be an independent part of the vehicle and it must be integrated with other components in the vehicle for it to successfully drive autonomously from a start destination to a final destination. For the best possible solution, GPS will be used because it can be integrated with a processor to be the main source of navigation for the vehicle to reach the final destination.

Multilateration

Multilateration is another technology which is currently used to track the location of different types of vehicles by using RF transponders. Multilateration, also known as hyperbolic positioning, is the process of locating an object by accurately computing the **time difference of arrival** (TDOA) of a signal emitted from the object to three or more receivers. It also refers to the case of locating a receiver by measuring the TDOA of a signal transmitted from three or more synchronized transmitters. One weakness of this technology is that it requires the presence of external antennas which may not always be present. It is also prone to interference. For an optimal solution, multilateration could be used as a form of tracking the vehicle to ensure that it is following the correct course to its predetermined destination. With the accuracy of multilateration, if the vehicle strays from its intended route then the user can be notified and make the proper adjustments.

Electric Compass

The electric compass is dead-reckoning sensor based on terrestrial magnetism. With an electronic map system with coordinates, the system can utilize readings from the electric compass to navigate from a starting point to the destination, provided the coordinates of the end point are initially identified. The major weakness in utilizing the electric compass is its sensitivity to external interferences of the magnetic field. The electric compass is based off the magnetic north which leaves error because of interference from steel or other metal buildings which can interfere with the accuracy of the compass. To address the inexactness of the electric compass, the use of two electric compasses integrated into one robust electric compass will efficiently cancel out the low-frequency interferences. This use of the technology would be sufficient and it is proven to work. To include the electric compass in the optimal solution would add another dimension of accuracy and it would serve as an assisted GPS to the primary GPS. The electric compass can assist in areas where the GPS signal may not be strong based on certain interferences that could arise from tall buildings or bad reception depending on the quality of the GPS system.

4. **Engineering Approach**

Preferred Solution

The challenge in creating a fully autonomous system is how to triangulate the location of a vehicle and the position of the users' destination. Thanks to Global Position System (GPS), we can always find the location of a vehicle through the help of satellites. Modern GPS use a

combination of GPS and Geographic Information System (GIS). With these two systems we are given the tools to calculate positions as well as routes. The problem arises in how to translate the instructions that are created by the GPS instruction to drive a system that will control a car.
In primary approach to the problem we plan on using a system which contains a computer, and two microcontrollers. One microcontroller will be in charge of receiving, interpreting GPS signal and then transmitting the GPS coordinates to a computer. The computer will contain our GIS as well as the coordinates of destinations. The computer will be the core part of the system that will interpret, plan, translate given instructions into a language that can be interpreted by the second microcontroller. The final microcontroller will be in charge of the motors and will move the vehicle. This microcontroller will act as a failsafe that will be able to calculate motor speed, and distance to be used in error correction to check errors transmitted from the GPS. These checks will be sent back the computer to correct errors in routes, and give feedback information to the user.
In our pursuit of a solution, we will be using our knowledge in microcontroller, programming, and signal processing to help aid us. At the end of this project we hope to learn more about embedded system, and how to construct and program across many different electronics to be able to work as one. The scope of our project does not include collision avoidance. This is only a subsystem of an overall system; collision avoidance is covered in the other subsystems.

Alternative Solution 1

An alternative design solution would be the use of multilateration to determine the location of the vehicle by computing the time-difference of arrival of a signal emitted from the object to three or more receivers. Multilateration allows for multiple transmitter/receiver locations to overlap for a stronger and more optimal signal strength area. The vehicle will be located and guided, using an RF transponder communicating with signals emitted from multiple towers or locations, through the route predetermined by the user. The location information will be passed on to a processor which will send directional instructions to actuators connected to the mechanical parts of the vehicle. The processor will also receive information regarding distance travelled from sensors connected to the vehicle. Due to the relative local position of the transmitter/receivers used in this method, the accuracy is much higher than the popular GPS. Unfortunately this is also its down fall as these transmitter/receivers are not common in all areas and would cost a great deal to install across the nation.

Alternative Solution 2

Another design option would entail the input of line by line directions by the user. The directions will then be sent to a central processing unit which will be connected to an electric compass. That way the user may enter the street names and allow the in system map to judge its position and heading by using azimuths and distances. This system requires the user to know the exact position of their starting point, as well as their ending point. The location device will be connected to a processor which will send directional instructions to actuators connected to the mechanical parts of the vehicle. The processor will also receive information regarding distance travelled from sensors connected to the vehicle. The benefit of the compass is that the user doesn't need to know the exact angles to turn at every corner. The internal map will have all this information inside it and will check it with the compass. Even with the compass, however, this system leaves too much room for user error. In a real world scenario the risk of the user entering an incorrect initial or final position would cause numerous uncorrectable issues. This system simple does not have the proper checks and balances.

5. Tasks and Deliverables

The solution will be implemented in a scaled version which will be tested to ensure full functionality. The project deliverables include

- Fully functional prototype of system integrated with a scaled auto vehicle. This prototype will perform all the features of the actual system design. The system will be demonstrated at the ECE Senior Design presentation day

- Manual which will include operating instructions as well as tips for troubleshooting any problems encountered in operating the system

In order to accomplish and meet the above deliverables, the following tasks will have to be completed:

Initial Design: The team will put together functional and design requirements for the proposed system

Design Proposal and Approval: The team will put together full proposal including possible solutions as well as project budget and requirements. Approval for selected solution will be sought from team sponsor and adviser

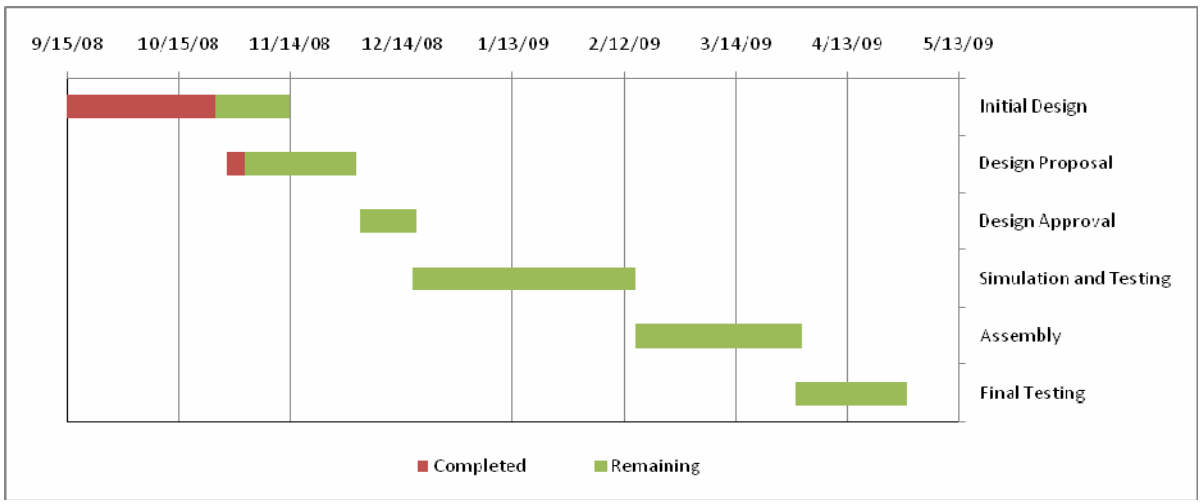
Simulation and Testing: Upon design approval, the team will commence simulation and testing using software tools to verify design solution. Solution will be modified to achieve best results from simulations

Assembly: Upon obtaining satisfactory results from simulations, the team will purchase parts for hardware implementation of the design prototype.

Final Testing: The design prototype will be tested to ensure it functions properly

6. Project Management

The project will span approximately 8 moths and tasks will be completed following the set timelines:



Team members have been assigned the following tasks:

Ozioma Obiaka

- Design test procedure for verifying functionality of protoype system
- Integrate robotic system with processors to allow for control of vehicle functions through instructions from the processor

Isaac Collins

- Build codes for micro-processing unit using required programming languages
- Design error checking system to ensure accuarte location mapping and distance reporting of the vehicle

Clifton Lomax

- Build codes for micro-processing unit using required programming languages
- Integrate GPS system and micro-processor so that location coordinates and driving distance are loaded onto the processor in the correct format.

Nicholas Baker

- Integrate robotic system with processors to allow for control of vehicle functions through instructions from the processor
- Perform tests on prototype to ensure full functionality

Endor Cooper

- Document all team proceedings and create operating and troubleshooting manual for the prototype system
- Perform tests on prototype to ensure full functionality

Budget: An estimated budget of about $1000 will be required in developing and testing a scaled prototype of the autonomous map follower system. Below is a preliminary cost estimate for components which will be used in building the prototype.

- GPS System
- Windows Embedded NavReady System: $100
- GPS Expansion Pack: $60
- 32 bit PIC microcontroller start kit: $60
- MPLAB C Compiler for PIC24 MCU: $500
- MatLab with Simulink: $100
- Lego Mindstorm NXT: $250

Facilities which will be utilized include the Mobile Studio Lab, FPGA boards, as well as other testing equipment in the Electrical Engineering Lab. Safety precautions will be observed in designing the system to avoid any injury to the team. In order to design not just a functional system, but also to do so within as prescribed by ethical engineering practices, the highest priority will be given to the safety of the system for its users.

7. Conclusion

The project will develop and build a system which allows a vehicle to autonomously navigate from one point to a determined destination. Spanning a period of 8 months, the team intends to deliver a scaled prototype reflecting the full functionality of the design, as well as an operating manual for the system. The system will also adhere to the relevant safety standards as defined by the relevant safety standard boards.

A key part of the system will be in utilizing an effective technology in accurately keeping the vehicle on track for its destination. The project will utilize GPS tracking system to obtain location coordinates which the vehicle will follow. The location device will be connected to a processor which will send directional instructions to actuators connected to the mechanical parts of the vehicle. The processor will also receive information regarding distance travelled from sensors connected to the vehicle. Other proposed solutions which utilize different location mapping technology includes the use of RF transponders for multilateration technology, as well as the use of an electric compass in navigating to the intended destination.

In executing the project a timeline will be adhered to for completing the various phases of design proposal and approval, simulation and testing, building and assembly, and final testing. Also various roles have been assigned to various team members towards completing the project. Facilities which will be utilized include the Mobile Studio Lab, FPGA boards, as well as other testing equipment in the Electrical Engineering Lab. The total design and implementation of the project will cost approximately $1000. The project will be sponsored by Chrysler and a company employee will also serve as a mentor to the team for the duration of the project.

8. References

Franson, J. (2004, June 1). *GPS Programming & .NET*. Retrieved November 1, 2008, from Dr. Dobb's Portal: http://www.ddj.com/windows/184405690

Google Earth KMZ / KML to GPS converter . (n.d.). Retrieved November 1, 2008, from http://www.brothersoft.com/google-earth-kmz---kml-to-gps-converter-64381.html

GPS Software Download Pages. (n.d.). Retrieved November 1, 2008, from http://www.gpss.tripoduk.com/download.htm

K J Parkinson, A. G. (n.d.). *FPGA based GPS receiver design considerations*. Retrieved November 1, 2008, from http://www.gmat.unsw.edu.au/wang/jgps/v5n12/v5n12p12.pdf

Machine Science On-line Store. (n.d.). Retrieved Novemeber 1, 2008, from http://www.machinescience.com/catalog/index.php?cPath=21&osCsid=fbc4d7f824b8c991d651ad966f01035e

McGrath, D. (2006, July 31). *Actel offers free IDE for 32-bit ARM7 MPU core*. Retrieved November 1, 2008, from Automotive Design Line: http://www.automotivedesignline.com/showArticle.jhtml;jsessionid=BUEEM5CIJLLMEQSNDLPSKHSCJUNN2JVN?articleID=191601198&queryText=%09+%09%09%09%09++Actel+offers+free+IDE+for+32-bit+ARM7+MPU+core

Microsoft patents lego-like modular GPS Navigator, camera, phone thingy. (n.d.). Retrieved Novemeber 1, 2008, from http://www.unwiredview.com/2008/09/18/microsoft-patents-lego-like-modular-gps-navigator-camera-phone-thingy/

PIC Global Positioning System IO. (n.d.). Retrieved November 1, 2008, from http://www.piclist.com/techref/microchip/gps.htm

PIC23DevBoardOptions. (n.d.). Retrieved November 1, 2008, from http://ww1.microchip.com/downloads/en/DeviceDoc/PIC32DevBoardOptions.wmv

The Global Positioning Systems (GPS) Resource Library. (n.d.). Retrieved November 1, 2008, from http://www.gpsy.com/gpsinfo/#mapping

9. Attachment: Final Design Requirement Form