Intelligent Cruise Control for Dangerous Landscape by using GPS

Tayar Myo Tun
University of Computer Studies, Mandalay
taryarmyotun@gmail.com

Abstract

The various positioning application meets strict needs such as car navigation, mapping, surveying, security, agriculture and so on. An Intelligent Cruise control system is simulated and demonstrated using GPS as the only sensor for position and heading. The key idea offered by this paper is to use GPS sensor for warning signals placed in the dangerous portions of the road. The warning system is built on GPS sensor with real time kinematics (RTK) functionality. It means that the receiver must be able to receive RTK corrections. This system consists of three components: a GPS receiver with RTK (Real Time Kinematics) function and a computer with software that evaluates the position of the cruise compare to the road model and issues warning if the cruise is outside or is heading outside the correct lane and warning to determine authorized speed in its zone of localization. With real-time information, the system can dynamically control the speed and direction of the cruise in real world and also predict road's incidents of the near future.

1. Introduction

Cruise accident is one of the major causes of death in many countries so that the field of Intelligent Transport Systems (ITS) is required to improve rapidly in the world. According to several statistics the majority of the Cruise accidents are caused by high-speed and disrespect of the inter-vehicles security distance. Many experts are currently working on different projects to increase the safety of automobiles and decrease the number of accidents on the roads. Based on the statistics, approximately 0.0023% of the civilians are killed in vehicles accidents in Myanmar each year.

Nowadays, cruise may drive highway miles with GPS to identify the location and condition of assets such as traffic control devices and signs, or survey critical mobility and safety characteristics of road networks, such as areas where there are dangerous curves, rough pavement, accidents, congestion, burst water mains, faulty traffic light and so on. [1]

To reduce the accident, lane tracking is one of the major tasks in autonomous urban driving. Lane tracking is an important topic in autonomous navigation because the navigable region usually stands between the lanes, especially in urban environments. Curve warning systems (CWS) have been recently developed that use a combination of global positioning systems (GPS) and digital maps obtained from a Geographical Information System (GIS), to assess threat levels for a driver approaching a curve too quickly; likewise, intelligent speed assistance (ISA) systems warn the driver when the vehicle's velocity is inappropriate, using GPS in combination with a digital road map containing information about the speed limits. However useful, these systems are inoperative in case of unexpected road circumstances (like road diversions, accidents, etc.) . [5]

An intelligent cruise control uses topographical map data for the road network. Topographical information is combined with GPS data to determine the position of the vehicle and the topography of the road ahead. Based on this information, the most efficient speed and heading of cruise profile is calculated every second.

2. Theoretical Background

GPS has two major benefits: firstly, coordinates provided by GPS, together with changes of the role angle, speed and acceleration help to distinguish between city streets and roads outside city. Secondly, comparison between dangerous points of the map and current coordinates of the car is facilitated. If the vehicle is close to risky locations, speed of the car will be limited. If the side distance is less than a critical value d_{limit}, then the cruise is in dangerous zone. The performance of the warning system depends on the ability to compute actual lateral distance d_{left} and d_{Right}.

2.1. GPS (Global Positioning System)

GPS, or Global Positioning Systems, is a satellite navigation system that provides the ability to determine locations anywhere on the earth. The system completed by the U.S. Government in 1994 is a constellation of about 24 satellites which emit coded signals that allow the user to very accurately determine their location on the Earth.

2.1.1. Components of GPS

The NAVSTAR system (the acronym for Navigation Satellite Timing and Ranging, the official U.S. Department of Defense name for GPS) consists of a space segment (the satellites), a control segment (the ground stations), and user segment (user and GPS receiver).

- *Space Segment*: 24 GPS space vehicles (SVs). Satellites orbit the earth in 12 hrs. 6 orbital planes inclined at 55 degrees with the equator. This constellation provides 5 to 8 SVs from any point on the earth.
- *Control Segment*: The control segment comprises of 5 stations. They measure the distances of the overhead satellites every 1.5 seconds and send the corrected data to Master control. Here the satellite orbit, clock performance and health of the satellite are determined and determines whether repositioning is required. This information is sent to the three uplink stations.
- *User Segment*: It consists of receivers that decode the signals from the satellites. The receiver performs following tasks: Selecting one or more satellites Acquiring GPS signals measuring and tracking Recovering navigation data

2.1.2. GPS Receiver

GPS receiver includes a time delay for the change of the vehicle speed since the first detection of the first signal that permits the vehicle to reach the part of the road affected by the second traffic signal. To get this positioning information, requires a user to have a GPS receiver. GPS receivers can store a sequence of locations (waypoints) and provide navigation information to each waypoint in that sequence. As each waypoint is reached, the next waypoint in the sequence automatically becomes the active waypoint GPS is already being used in a number of ground vehicle applications. The GPS receiver allows easy to use track plotting and navigation capabilities. The following GPS functionality is currently supports when it is connected to the included GPS receiver.

- View current position
- View current track
- View precision speed and heading from GPS receiver
- Save track and way points.
- Travel a route and navigate from one waypoint to the next.

Most GPS receivers have the ability to record location data in the form of points (example, location of a building), a line (example, a trail) or an area (example, a lake). This can then be converted to a file that can be directly imported into GIS system. This can be extremely useful for land trusts - any work in the field can be accurately mapped and uploaded directly into GIS.

- Baseline Mapping
- Photo Points
- Field Surveys, Natural
- Field Surveys, Man-Made
- Locating features in the Field

2.1.3. Precision of GPS Positioning

Depending on availability of RTK corrections and the quality of GPS signals, there are four types of solution that a RTK GPS receiver can produce:

- RTK fixed solution; expected precision is on cm-level. This solution is available only when uninterrupted GPS phase observations and RTK corrections are available.
- RTK float solution, expected precision is on dm-level. This solution is typically available shortly after the start of the receiver or after the re-acquiring of GPS signal or RTK corrections.
- DGPS solution, expected precision is 1 - 3 m. In this case the RTK corrections are available, but GPS signal is too weak to perform phase observations. This is usually the case when many of available satellites are behind the trees.
- Autonomous solution, precision 10-20 m. This solution is generated, if the RTK corrections are not available.

2.2. Kinematic Model for Positioning

Kalman filter seems to be the most appropriate tool for the computation of position, velocity and acceleration of the car in real time. In statistics, the Kalman Filter is a mathematical method named after Rudolf E.Kalman. The Kalman Filter is a recursive estimator. This means that only the estimated state from the previous time step and the current measurement are needed to compute the estimate for the current state. The Kalman Filter produces estimates of the true values of measurements and their associated calculated values by predicting a value, estimating the uncertainty of the predicted value, and computing a weighted average of the predicted value and the measured value. The estimates produced by the method tend to be closer to the true values than the original measurements because the weighted average has a better estimated uncertainty than either of the values that went into the weighted average.

Standard Kalman filter formulation described with the following steps:

1. Initialization: estimation of starting values for position, velocity, acceleration and their covariance matrix.
2. Prediction
3. Computation of gain matrix
4. Update state vector using measurements from current epoch and Store state variables for the next epoch
5. Update covariance matrix and Store covariance matrix for next epoch

Steps 2 to 5 are repeated for every new GPS observation [4].

2.3. Model of Landscape or Road Model

A precise road model is a prerequisite for correct functionality of the warning system. By road model we understand a database of coordinates of points that describe the geometry of road. Such database can be created by surveying discrete points along the road's edges or along the middle line. Usually, the existing databases are not accurate enough for this purpose. A section of the road between two surveyed points refers as segment.

2.4. Neural Network

An artificial neural network (ANN), usually called "neural network" (NN), is a computational model that tries to simulate the biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connection to computation. Neural networks are non-linear statistical data modeling tools. Basic applications of NN are function approximation, fitness approximation and modeling, classification, pattern and sequence recognition.

In the computational ANN model, the synapses of the neuron are modeled as weights. The strength of the connection between an input and a neuron is noted by the value of the weight. Finally, an activation function controls the amplitude of the output of the neuron. An acceptable range of output is usually between 0 and 1, or -1 and 1. In most cases the ANN is an adaptive system.

The learning procedure tries to find a set of connections (or weights) w that gives a mapping that fits the training set well. Furthermore, neural networks can be viewed as highly non-linear functions with the basic form:

$$F(x; w) = y \qquad (1)$$

where x is the input vector presented to the network, w are the weights of the network, and y is the corresponding output vector approximated or predicted by the network. The output layer, on the other hand, is the available sign types in the training set.

2.5. Error Reduction Methodology

In order to reduce the errors and optimum calculation, this system presents the simple intelligent method, called Map Matching Method. It is described in three steps, firstly it defines the position of dangerous landscape in the Map Coordinate. Secondly, it identifies the position of cruise or road segment received by GPS, being trained by NN, and then obtain the spatial data of the special code been defined. Finally, it calculates the nearest point from the position to the dangerous road segments or to the dangerous zone and find the remaining distance. (X, Y) refers to the GPS coordinates of cruise and (Xi, Yi) refers to one point on the road segment. (Will be trained to NN).

3. Description of Intelligent Cruise Control System

The proposed system issues a warning based on the computed lateral distance $d_{Left,}$ d_{Right} between the cruise and the edge of the road and front distance between the cruse and dangerous point. X and Y coordinates of the current location are provided to the controller by the GPS. Therefore, it can easily refer to the location of the car whenever it needs to make a decision[4].

In order to determine the threshold for maximum speed and d_{limit} of a vehicle, an artificial neural network is utilized. Since the behavior of the system changes according to the location of the cruise (city, town, road, street, etc.), the weights of the network are loaded corresponding to the location. Detection of the location is determined by measuring the changes of the role angle, acceleration, and GPS system coordinates. After loading the weights of the neural network, the network is activated. Inputs of the network which have been prepared in the preprocessing stage are delivered.

The network estimates the maximum allowable speed based on the provided knowledge and delivers this threshold to the speed control system. The current coordinates of the cruise are compared with coordinates of dangerous locations on the map. These locations are of high risk of collision and accident.

If vehicle is less than, half a kilometer away from a dangerous location, this state is reported to the speed control system so that proper action is taken. If this speed is more than the maximum threshold, system automatically takes part and reduces the speed of the car. Since the car speed must be limited well before the predefined dangerous points, measuring the distance to these points is performed using the following equation:

IF | D(x,y)-D(xt,yt) | < 500 THEN Limit the speed and warning signal (2)

D(x,y) : Current position of the cruise

D(xt,yt): Position of dangerous points

If the side distance is less than a critical value d_{limit}, then the cruise is in dangerous zone. The performance of the warning system depends on the ability to compute actual lateral distance d and it depends on update frequency f and hardware delay HD.

GPS receiver waits for the corrections, which are generated with 1 Hz frequency. It means that the position is available only once per second with certain delay, which depends on the communication link between reference and roving receiver. The delay is in range of 1 – 2 s. In this application a higher update frequency and shorter delay is required. If we consider that we need at least one position update to compute the driving direction, then the total delay TD, i.e. difference between time of last known position and the time when the warning system computes and displays new position.

During time TD the motion of the cruise is not sensed and the lateral distance is changed by Δd. Δd depends on the velocity of the cruise, error in course ε, update frequency f and hardware delay HD. These values can be used for choosing a suitable value for safety marginal d_{limit}.

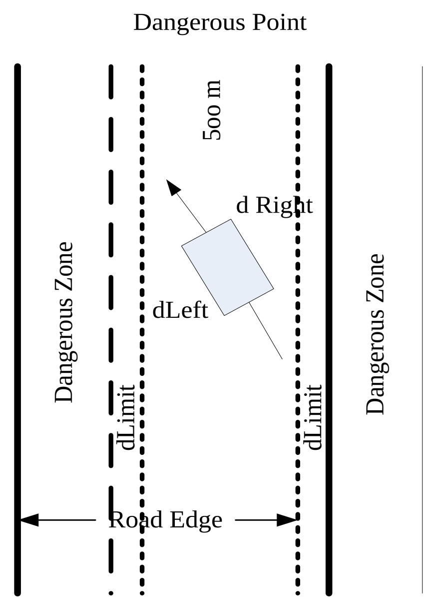

Figure 1. Dangerous zone, dangerous point and lateral distance

The proposed system reads in position from GPS receiver, finds the segment in the road model and computes the distance to the road edges. If the left and right side distance is shorter than critical value d_{limit}, then the system triggers alarm “In dangerous zone”. The GPS position is then used to update state vector using the above-described Kalman filter and predicted position (3 s ahead) is computed. If this predicted position falls into the dangerous zone, the alarm “Heading into dangerous zone” is triggered.

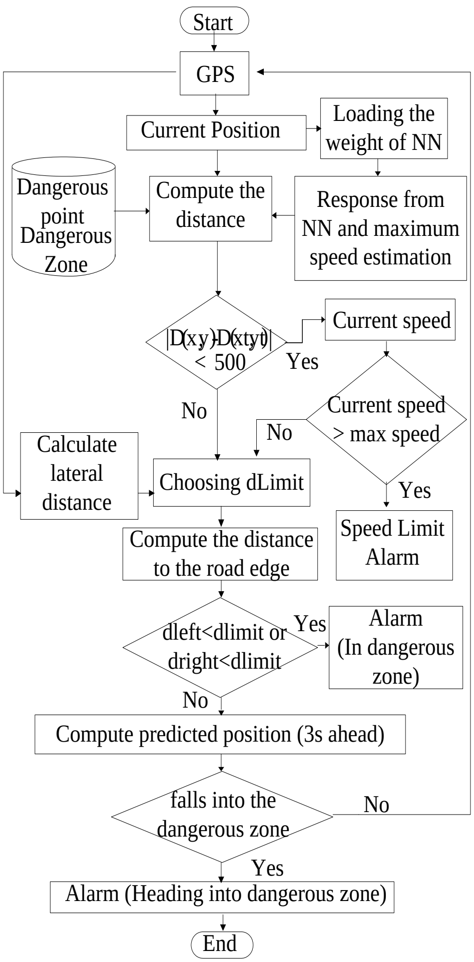

Figure 2. System flow diagram for intelligent cruise control

This risk is largely due to restricted sight distances and the corresponding time available to recognize that a hazard is present and decide to take avoidance action - the risk is not greatly affected by driver ability or vehicle braking performance. Regular speed limit is 40km/h. the risk of involvement in a casualty crash in travelling speed above 60km/h.

As speed increases the task demand rises and the driver’s capability is reduced One of the key findings is that, for a given set of road conditions, there is a optimum maximum speed, above which the risk of fatal accidents can be expected to rise more or less exponentially.

One of the key findings is that, for a given set of road conditions, there is a optimum maximum speed, above which the risk of fatal accidents can be expected to rise more or less exponentially. It is very important that speed limits are set, and enforced, according to the actual conditions so that we do not exceed the optimum level for those conditions, otherwise a disproportional increase in fatalities can be expected. It is not advisable to set speed limits according to the speeds perceived as "safe" by given suitable input, "expert" computer systems are a much better way to decide on appropriate speed limit. As speed increases the task demand rises and the driver’s capability is reduced.

4. Conclusion

One of the main purposes of this system is to facilitate accurate cruise position information distribution with regard to safety services and operations. The speed of the cruise is reduced before the dangerous landscape to avoid unnecessary braking and the heading of the cruise is automatically alarm for dangerous zone. This paper approaches to study feasibility of using RTK GPS as a sensor in the system that can warn the driver if the cruise is outside the correct lane or is heading there and reach high speed near the dangerous point.

The ability to estimate vehicle dynamic parameters in real-time has been demonstrated using an Extended Kalman Filter on experimental data. This is an ongoing research and the result with come out after doing experiments.

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References

[1] Adrian Guan, Steven H. Bayless, and Radha Neelakantan , “*The Intelligent Transportation Society of America”* (ITS America)(2011-2012)

[2] Michael O’Connor, Gabriel Elkaim, and Dr. Bradford Parkinson,”*Kinematic GPS for Closed-Loop Control of Farm and Construction Vehicles”,* Stanford University

[3] Joshué Pérez *, Fernando Seco, Vicente Milanés, Antonio Jiménez, Julio C. Díaz and Teresa de Pedro, “*An RFID based Intelligent Vehicle Speed Controller Using Active Traffic Signal”*.

[4] Milan HOREMUZ, Sweden, “*Car Collision Warning System Based on RTK GPS”,* Stockholm, Sweden 14-19 June 2008

[5] M. Caner Kurtul, *“Roads Lane and Traffic sign Detection and Tracking for Autonomous Urban Driving"*, Graduate Program in Computer Engineering Bogazici University,2010

[6]Nguyen Thanh Hung, Hideto Ikeda, Nikolaos Vogiatzis, ZinLin, “New Environment CREPE for transportation Control and its Effectiveness”, Ritsumeikan University, Japan, 2011