Development Of An Intelligent Speed Adaption System Based On Segmentation Incorporating A Central Surveillance Unit

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Abstract— **In this paper, we review the research findings of the Intelligent Speed Adaption (ISA) system and propose an effective way of implementing this technique in developed, as well as developing countries with reasonable system reliability. Instead of digital mapping, we focus on widespread implementation of a road safety system by way of dividing the road transportation links of a vast region into segments. Besides support towards widespread implementation, the system has been designed to provide enhanced storage performance and simple to implement real time data update capability. The overall scheme has been developed as an organized interconnection between sub-systems and databases to ensure that essential data transmission to and from the moving vehicle occurs such that the safety of the road is enhanced. The design also incorporates the idea of a central surveillance unit which would not only store the data related to co-ordinates, corresponding speed limits and speed limit violators but also aid close supervision of running vehicles, thereby serving the supplementary task of improving homeland security.**

Keywords: Intelligent Speed Adaption(ISA), Intelligent Transportation System(ITS), Global Positioning System(GPS), database.

1 Introduction

Road safety is one of the major issues of concern in this era of Intelligent Transportation System (ITS). In spite of advancement in this field of research, death toll and injuries caused by road accidents remain high. Road traffic injuries represent about 25 percent of worldwide injury-related casualties with an estimated 1.2 million deaths each year. In the year 2006 in Asia alone, more than half a million people were killed and 20-30 million injured in road crashes, at an economic cost of some 100 billion USD. It is estimated that road traffic injuries will be the third leading cause of life lost by the year 2020 [1]-[2]. Though multiple reasons are responsible for road accidents, one of the most significant factors behind this enormous epidemic remain over-speed or violation of speed limit. Research shows that in a 60 km/h speed limit area, the risk of involvement in a casualty crash doubles with each 5 km/h increase in traveling speed above 60 km/h [3]. Hence, excessive speed not only increases the risk of accident, but also the severity of damage. So road safety authorities around the world have devoted considerable resources to address the problem of over speed. The countermeasures which have gained attention in this regard include Intelligent Speed Adaptation (ISA), Autonomous or Adaptive Cruise Control (ACC) and Intelligent Cruise Control (ICC) system.

ISA is the generic name for an advanced system in which the vehicle knows the speed limit and is capable of using that information to give feedback to the driver or limit maximum speed. The action can be advisory or 'passive', where the driver is warned or 'active', where there is some degree of automated control of vehicle speed. The technologies involved in these systems include Global Positioning System (GPS), radio beacons, dead reckoning and/or optical recognition. In spite of being a high tech safeguard system, ISA has some shortcomings. This system operates on the basis of generation of digital maps and associated speed limits, where annual updates have to be conducted resulting materials and administrative expenses. Also storage media and reading capability have to be increased [4]-[5]. ACC automatically accelerates or decelerates a vehicle to maintain a selected time gap to reach a desired velocity or to prevent a rear-end collision. The ACC sensors, usually laser based ones, detect and track the vehicle ahead for measuring the actual distance and speed difference [6]. Similar to the ACC, the ICC system of speed control is capable of maintaining a car-to-car distance in order to prevent any collision. A vehicle equipped with ICC contains a radar unit which adjusts the speed based on the relative speed and distance of the vehicle in front [7]. Like the ISA, ICC and ACC also have some shortcomings. Laser-based ACC systems cannot detect vehicles well enough in adverse weather conditions or track extremely dirty (non-reflective) vehicles. On the other hand, radar based ICC system is used in few luxury vehicles only. Moreover, upto now, both these systems are only optimized for the user's driving

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comfort and safety, instead of providing information on potential speed limit violators to the authority concerned.

Thus, each speed adaptation system, namely ISA, ACC or ICC has limitations when widespread implementation, efficiency of operation and cost effectiveness become the matter of concern. Also these techniques do not have a way of informing the road safety watchdog of a potential danger or helping the authority concerned to identify speed limit violators. Another issue related to road safety is incremental map update for advanced in-vehicle application. Digital maps updated during will play a major role in current and future in-vehicle ITS applications. Today's in-vehicle navigation systems are location-based and orientation of the vehicle is determined using digital road maps stored in a CD-ROM or DVD, the periodic updates of which are available on replacement disks only [8]-[9]. As the real world changes every day, an important challenge is to keep the map as up-to-date and as accurate as possible. As far as road safety is concerned, dynamic update of location and corresponding speed limit is a major issue of concern.

Taking into consideration the described limitations of the existing systems, in this paper we put forward a novel approach to over speed detection, control and management. The proposed system is an intelligent combination of Ground Packed Radio Service (GPRS) based mobile communication, GPS, microcontroller and a central surveillance unit (CSU). The proposed design scheme, instead of using digital mapping, introduces the concept of dividing a large area into segments in order to facilitate widespread implementation of speed control measures in an effective way [10] as well as easy dynamic update of data related to locations and corresponding speed limits. In addition to this, the proposed multipurpose system offers a high-tech way of on-road surveillance which might be motivated by a perceived need of homeland security.

2 System Topology

The system we have designed is basically a passive ISA system containing the added features of run time dynamic update, feasibility of widespread implementation and system reliability.

The design scheme can be illustrated on the basis of three databases: database1 (DB1), database2 (DB2) and database3 (DB3). The efficient co-ordination of these three databases is an integral part of our design.

DB1 sets the reference of comparison for the moving vehicle. It is actually a storage device used inside the vehicle (e.g. Electronically Erasable Read Only Memory or EEPROM). This database will be updated via mobile communication and microcontroller based interfacing each time the vehicle crosses a road segment. As a result DB1 contains real time speed limits of a road when a vehicle is plying along it. The structure of DB1 and DB2 are almost identical. The only difference is that DB1 contains the longitudes (LNG), latitudes (LAT) and limiting velocities (LV) of a particular segment, whereas DB2 contains these values for all the segments brought under the control system. Also to be noted that this database contains a segment number (SN) which is sent from DB2. This provides the authority with the information about which vehicle is running along which road segment.

DB2 is the central database containing the LVs corresponding to LNGs and LATs of roads brought under the supervision of our advanced control system. The LVs are to be set by experts based on the roads. This database also contains SNs, which are the serial numbers corresponding to each segment. DB2 is to be a voluminous one containing a large amount of data necessitating the use of large storage device. It is to be located at a safe establishment under the maintenance of the CSU and can be easily modified when needed.

DB3 is the third and final database in our system which contains the information of all the vehicles those have violated speed limits. This database is updated only when the interrupt request (IR) is sent to the central surveillance unit. Like DB2, it is to be maintained by the CSU. This database contains the identification number or TAG of the vehicle that has violated speed limit, the serial no. of the segment at which the speed violation took place, the approximate LNGs and LATs of the location. It also contains the speed at which the vehicle over sped and the time of incident.

A driver brought under the supervision of our system would be warned if he tries to exceed the speed limit of the road concerned. A microcontroller used as an in-vehicle component of our system serves as the decision making unit and would carry out the following operations.

2.1 Main Operation

The main operation of the microcontroller is to take as input the current location from GPS, runtime speed from the speedometer and then compare this speed with the speed limit stored in DB1 for the corresponding location. If the vehicle maintains its speed below the pre-specified speed limit, the microcontroller would carry on this operation without any interrupt.

2.2 Over-speed Subroutine

This subroutine will be called only if the vehicle exceeds the speed limit for more than a predetermined time period T1. When the subroutine is called, it enables the microcontroller to send a warning signal to the driver so that he reduces the speed of the vehicle. However if the speed is not controlled within another time period T2, the microcontroller would prompt the transmitter to send a message signal using the pre-specified communication technique. The message signal would contain three primary informations: the location (longitude and latitude) of speed violation, speed of the vehicle and time of speed violation. This message signal, which is sent to DB3, is saved for action to be taken by the authority concerned.

2.3 Request Subroutine

Like the over-speed subroutine, this subroutine is also loaded into the microcontroller. It would be called only when the vehicle crosses the transition point (TP) existing between two adjacent road segments (to be discussed in the segmentation part of the paper). This subroutine will enable the microcontroller to transmit a request to DB2 of CSU. In return, the CSU will send the vehicle information corresponding to the next road segment so that the microcontroller can carry on its main operation of comparing and matching.

2.4 Saving Data

The network used for mobile communication normally does not exist homogenously throughout a vast area. As a result, it is possible that the moving vehicle may fail to transmit data to the CSU even if an interrupt or a request subroutine had been called. In this situation, the microcontroller would perform the operation of saving data. The data to be transmitted will be saved in the EEPROM of the microcontroller and preserved until the communication network is strong enough for data transfer with the CSU.

2.5 No Value Match (NVM)

If the car is out of network at the time of crossing the transition point, it will send the real time data to CSU after regaining network connection. CSU will compare the LNG and LAT with all the segments and find out the SN of the vehicle. Then it will send the segment data to DB1 where it will be stored for subsequent use. Thus DB1 will be updated dynamically, thereby fulfilling the objective of realtime data update.

3 Segmentation

Segmentation introduced here is the concept of dividing a vast road transportation link into a number of segments based on different structural and situational variables which include LNG, LAT, LV, road structure, availability of communication network etc. The idea of segmentation comes from the fact that we have insufficient storage capability of the storage devices available. It is not possible for any storage device in a moving vehicle to store the LNG, LAT and LV of every road co-ordinates of a vast area at a time. So, we need segmentation of the roads so that at an instant DB1 or the storage device requires only to store the data of the segment corresponding to the runtime location of the vehicle. Besides, segmentation helps the CSU to track a vehicle at any time and identify its location. Present ISA system operates on the basis of generation of digital maps and associated speed limits, where annual updates have to be conducted. Also storage media and reading capability has to be increased [5]-[6]. In our proposed system, the concept of segmentation will not only reduce the complexity of storing large scale data but will also ensure continuous surveillance of each vehicle by the road safety watchdog.

3.1 Indexing

The task of indexing is two fold; firstly, the co-ordinates in a specific segment have to be indexed for each and every location values of LNG and LAT. Secondly, all the segments brought under the supervision of our ISA system have to be indexed. For example, if all the roads of a country are divided into ‘N’ number of segments then the segments are indexed from ‘0’ to ‘N-1’. Again, each segment containing ‘M’ data points is indexed from ‘0’ to ‘M-1’.

3.2 Transition Points

The process of segmentation has a major shortcoming in the sense that a vehicle will contain only the data corresponding to the segment where it is plying. When a moving vehicle reaches the end of a segment, it needs to load the data of the next segment data from DB2. In this case, if the vehicle sends a request having reached the end of a segment, there will be some time lag for data transfer, receipt and loading. As a result, the microcontroller may not be able to check the speed limits for a number of locations close to the starting point of the new segment. To tackle this problem, transition points are introduced. Each segment will have two transition points. A segment will have these transition points at specific longitudes and latitudes fixed by the CSU.

The location of TP in a segment is predetermined in DB1 along with other values. When a vehicle reaches at the end of TP, it transmits a request to the server for next segment data. As a result, it gets the required segment data before entering the next segment.

3.3 Index Flag

The indexing of a specific segment depends on the direction of the vehicle entering that segment. The main server, when transmitting data of a segment to DB1, will set the segment indexing such that the entry location of the vehicle would consist the lowest index, whereas the exit location of the segment would contain the highest index. Let there be two cars entering segment 2 from opposite directions. Segment 2 (S2) has ‘M’ number of data points. For car1 the indexing will be ‘0’ to ‘M-1’ but for Car2 the indexing will be from ‘M-1’ to ‘0’. The

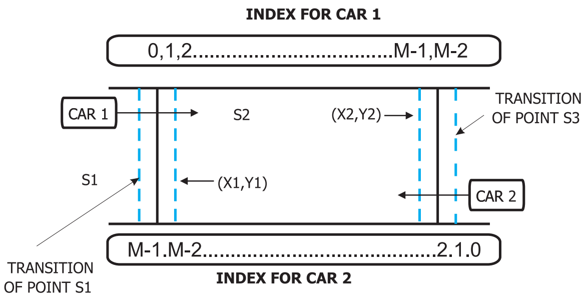

Figure 1: Transitioin Points and Indexing

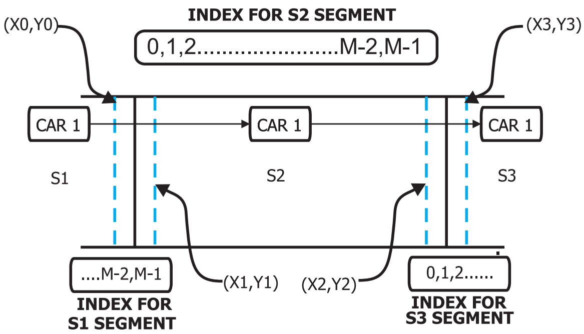

Figure 2: Vehicle moving towards increasing index

indexing for Car1 and Car2 is shown in the Figure 1.

Therefore the position of transition points of a segment will not vary but their index number may vary according to the vehicle's direction.

In Figure 1, (x1,y1) and (x2,y2) are the lower and higher transition points for Car1, but for Car2, (x1,y1) and (x2,y2) are the higher and lower transition points respectively.

Index flag (IF) is an indication for a vehicle to make a request for the next segment's data. If a vehicle has IF= 0 while crossing a transition point, it will transmit no request whereas it will transmit a request for the next segment's data if IF= 1. IF will change its state only when a vehicle reaches a transition point. At that time the microcontroller will check whether the vehicle is crossing the transition point in ascending or descending order by comparing the previous and present value of index traversed. At that instant four possible cases may arise These are as follows,

3.3.1 Case 1

If a vehicle crosses the lower transition point in a direction such that it traverses the index numbers in ascending order, then it has IF= 0, at that point.

In Figure 2 Car1 passes the transition point(x1,y1) of segment S2 in a direction such that it has IF= 0. So,

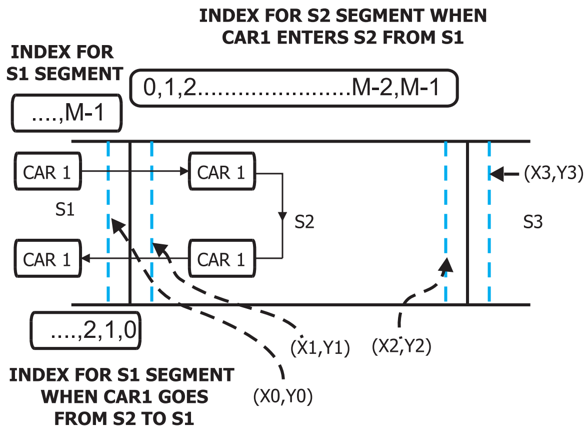

Figure 3: Vehicle moving towards decreasing index

at this point Car1 transmits no request for next segment data.

3.3.2 Case 2

If a vehicle traverses index numbers in descending order at the time of crossing the lower transition point then it will have IF= 1.(This case is discussed later) Similarly,

3.3.3 Case 3

If a vehicle crosses the higher transition point in a direction such that it traverses the index numbers in ascending order, then it has IF= 1, at that point.

3.3.4 Case 4

If a vehicle traverses index numbers in descending order at the time of crossing the higher transition point then it will have IF= 0. (rare case)

The following example, with reference to Figure 2, illustrates how the transition point and index flag is used to transmit request for next segment data when a vehicle is moving from one segment to other. Let a car is moving from segment S1 to S2. During the time it was moving in S1 segment it had S1 segments data stored in DB1. When it reaches the end transition point of S1(x0,y0), it has IF= 1, (as it is traversing S1 index in ascending order and passes the higher transition point i.e. case 3). So, it transmits a request for the S2 segment data and consequently enters the S2 segment with new data loaded in the storage device i.e. DB1. As the vehicle travels further and reaches (x1,y1) point, it sends no request to the CSU as it has IF= 0 (Lower transition point and traversing in the ascending order, case 1)

Thus moving forward it reaches (x2,y2) point and has IF= 1, (case 3), and sends request for next segment data. Finally it enters S3 with data of S3 loaded in its DB1.

A different situation occurs when the vehicle turns backward during traveling in segment S2 and moves towards entering segment S1 as shown in Figure 3. At the time the car was traveling from segment S1 to S2 it had passed the transition point (x0,y0) in such a way that IF= 1 (Case :03) and DB1 was loaded with data of segment S2. When the vehicle turns backward and reaches the transition point (x1,y1), it is actually traversing the index numbers in descending order. As (x1,y1) was stored as the lower transition point for S2 segment (Case :02), so the vehicle contains IF= 1, and sends a request for the data of segment S1. After entering S1 with the data loaded in DB1, it reaches (x0,y0) but sends no request at this time as, (x0,y0) is now the lower transition point and it traverses in ascending order, IF= 0 (Case :01). Thus, index Flag and transition point is used to send request for upcoming data segment at the time of moving from one segment to another. The efficiency of segmentation process largely depends on the availability of data at the right time. Sometimes a vehicle may not be able to receive the next segment data before entering that segment due to weak mobile network. In this case, the microcontroller will notice the unavailability of data as it will fail to match the position(x,y) from GPS to its stored data. Momentarily the MC will send a request of data unavailability to the CSU. The MC will continue sending request at a regular interval until the required segment data is received. To tackle this problem the roads should be segmented such that the initial and final end of each segment is well covered by the mobile network.

4 Simulation Results

4.1 Illustration for OverSpeed Interrupt

In this paper we have presented MATLAB simulation of our over speed interrupt process. This simulation reflects a small part of the total operation but it is the core of other operations. Results are shown in Figure 4. It is already shown that a microcontroller is used for decision making in our system and storing data or transmitting data to and from vehicle via mobile network. Our simulation consists of a status() Function and CentralDatabase() Function. For our Central Database we have assumed some data of longitude, latitude, Limiting velocity, Index Flag (IF) and Transition Flag (TF). Then we have let Matlab to take some random variables using rand() to generate some value on realtime velocity. So the realtime velocity is random for every simulation. Ucstatus() function has been written to get the operation in realtime. It takes realtime velocity, limiting velocity, latitude and longitude. It checks longitude and latitude to the corresponding latitude and longitude stored in the

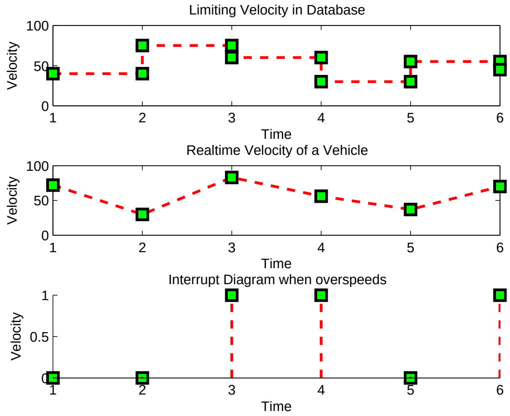

Figure 4: Matlab simulation for OverSpeed Interrupt

EEPROM (DB1) with the help of microcontroller and if the realtime velocity becomes greater than the limiting velocity, it calls a subroutine Interrupt to transmit this information of violation to the central database (DB2). From our simulation it is shown that Interrupt has been called when realtime velocity becomes greater than the limiting velocity.

5 Conclusions and Future Work

The ongoing development in the fields of telecommunication engineering, specially improvements in GPS, GPRS and mobile communication shows that efficient use of these technologies in the realm of research towards road safety is gradually becoming a demand of the day. The extent of GPRS and mobile communication is on the increase not only in developed countries, but also in developing and underdeveloped countries. Also the world has seen huge advancement in the fields of database management and processing and handling of large scale data. With these contemporary issues in mind, we introduce in this paper an approach towards the implementation of ISA in widespread areas making optimum use of modern technologies. We also believe that our proposed system would be a big stride towards the improvement of homeland security in addition to the enhancement of road safety. On the other hand, the cost of sending and receiving data at every instant might seem ambiguous. But proper selection of segments, the real time availability of data, close supervision of the CSU can outdo the cost issue. The major sectors where our proposed system can surpass the traditional ISA system is that once installed our system would be more efficient and any change in data can be done instantaneously. The system's inherent dependence on the accuracy, availability and effectiveness of GPS, GPRS and mobile communication obviously marks its limitations and necessities further studies. But the upward trend of technology undeniably inspires the widespread realization of ISA through successful combination of these states of the art and thus make ISA a commercial reality rather than an experimental novelty.

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