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Monte Carlo GPS Based Solution for Speed Limit Indicator

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Abstract: A comprehensive research has been undertaken to design and develop the GPS based, low cost and easily installable speed limit indicator in public and private vehicles. The device includes the building efficient GPS mapping technique for defining sentinels and a database for sentinel's storage utilizing minimum memory. These sentinels contain all concerned information required for navigation. Road safety is a crucial issue, ignorance of which can lead to fatalities. These fortuities happen due to speeding which often occurs due to lack of available information about speed limits on particular roads. An algorithm is developed and implemented in C language for simulation purposes by analysing complexities of road structures. Various road tests are performed to illuminate the technical problems in real time. Roads characteristics are examined and different hazards have been optimized through algorithm to resolve problems, faced by drivers. More importantly, it has been implemented within a Field Programmable Gate Array (FGPA), which verifies the simulation result as well.

Key words: GPS based . speed limit . road safety . GPS mapping . road architectures

INTRODUCTION

The efficient control of speed limit and management of transportation network decreases the probability of road accidents. Intelligent Transport Systems (ITS) have substantial capability to enhance the traffic safety performance. Different roads have various speed limitations depending on the vicinity of the road. In order to improve road safety many European countries and North American states are stringently enforcing road speed limits. The numbers of versatile experiments were performed for speed limitation at inside build-up areas and outside build-up areas. Hence authorities, Organisation for Economic Co-operation and Development European Conference of Ministers of Transport (OECD/ECMT) decided speed limits depending on road category [1-3].

Consideration of variable speed limits under various conditions bring an idea of implying different speed limitations at different times on the same road, depending on vicinity of road and frequency of the vehicles on that road during these specified timings [4]. Many devices have been made and are available in market which inform the drivers about road speed limitations and speed detection cameras reaching ahead. As these are not proposed to be housed in buses and trucks, therefore these devices lack generality. These devices have fixed speed limits for the same points for all timings of the day irrespective to frequency of vehicles on specific stretch of road. These devices are much expensive due to complex technology in terms of hardware and software, so difficult for drivers to afford.

This GPS Based In-Vehicle Speed Limit Indicator was undertaken to accomplish such an economical device that can be mounted in a vehicle that informs the driver about speed limit of current road and any violation of the current speed limit considering the rush hours of the day so that fatality rate could be minimized.

The design was developed by using commercially available GPS receiver to track vehicle coordinates in real time and programmed controller to retrieve the speed limit for current location from the database, compare limit with current speed and inform user about the status whether it is normal or over-speeding. A block diagram of the system is given in Fig. 1.

This paper includes development of a simple technique for GPS mapping which provides ways of tackling the novel problems which occurs due to road characteristics and while survey of roads to measure sentinels by analyzing environmental conditions.

GPS MAPPING

The mapping technique used in the design involves mapping a region without graphical drawings providing

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Table 1: Sentinels at Lancaster University

Location	Latitude	N	Longitude	Direction	Bearing angle	SL (Mph)
1	5400.3601	N	247.1985	W	167.3	5
2	5400.3601	N	248.1985	W	167.3	5
3	5400.3450	N	247.1621	W	178.6	10
4	5400.3542	N	247.1759	W	143.3	10
5	5400.3477	N	247.0831	W	269.1	10
6	5400.3515	N	247.1175	W	88.8	10
7	5400.3973	N	246.9949	W	202.0	20
8	5400.3833	N	246.9964	W	21.5	20
9	5400.4535	N	246.9564	W	200.1	20
10	5400.4506	N	246.9492	W	22.5	10
11	5400.5227	N	246.9308	W	137.3	10
12	5400.4642	N	246.9451	W	21.2	10
13	5400.6135	N	246.9347	W	182.7	10
14	5400.5802	N	246.9425	W	357.5	10
15	5400.6125	N	246.9793	W	270.6	10
16	5400.6273	N	246.9731	W	78.2	10
17	5400.6196	N	247.0458	W	268.3	10
18	5400.6196	N	247.0539	W	89.8	10
19	5400.3481	N	247.2552	W	269.4	10
20	5400.6455	N	247.3263	W	336.7	10
21	5400.6043	N	247.3015	W	182.2	5
22	5400.5933	N	247.3058	W	0.0	5
23	5400.5462	N	247.3022	W	180.0	5
24	5400.5031	N	247.2861	W	339.1	5

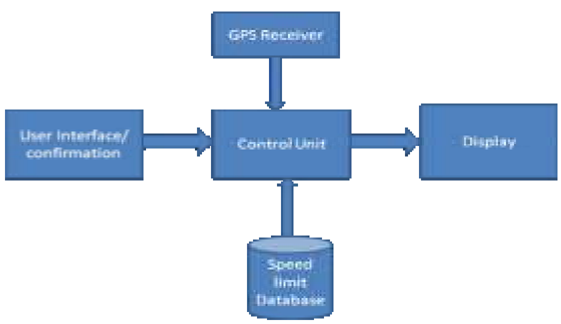


Fig. 1: Block diagram of GPS based speed limit indicator

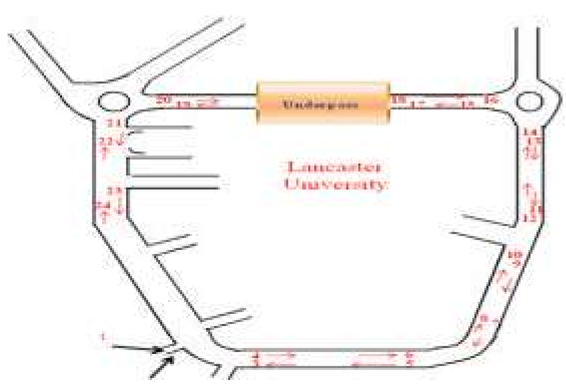


Fig. 2: GPS mapping for selected points

user with simplified and minimum explicit information about general speed limitation of that zone and the specified limits for critical locations, where the user is currently travelling. These speed limits change in rush hours. The region selected for mapping is the roads surrounding the academic area in Lancaster University, shown in the Figure 2. It represents the assignment of the positions assessed for mapping, that fulfilled the criteria of the most of the vital bespeaks.

- The locations 21, 22 and 23, 24 are passing through neighbourhood of nursery/primary school and sports complex (running 24 hours) respectively having large number of pedestrians all the times, so minimum speed limit are assigned down there i.e. 5 Mph.
- Same speed limit of 5Mph has been fixed for 1and 2 as these points were around zebra crossing and main entrance to residential area.
- The marked points 3, 4, 5, 6, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 lied near offices and academic building where the speed limits are variable.
- The locations 7, 8 and 9 are normal road points in the zone that had no building in the vicinity, so speed limit at there is normal zone limit, i.e. 20Mph, however during congestion these limits were changed towards lower values.

The number of pedestrian, bicyclists and vehicles vary with respect to different locations, i.e. offices and academic buildings, so speed limits changed over there in the same respect. Speed limit varied between 10 to 20 Mph depending on frequency of operators of that area.

The numbers of sentinels nearby academic, commercial and recreational development areas have strong influence on vehicle speed limits [5]. The Parameters required for speed limitation of those sentinels shown in the Fig. 2 are listed in the Table 1.

The sentinels are digital discrete numbers, representing the point coordinates, bearing angle and speed limit, which do not require huge storage space as compared to those which involved graphical information for each assigned point. This reduces the complexity of both software and hardware design and minimizes the cost tremendously.

GPS satellites transmit 12 NMEA streams explaining different aspects of navigation. GPRMC is one of those NMEA sentences that contain all information required for speed limit indicator. Sentence received at location 10 mentioned in Table 1 is shown as follow:

$GPRMC,170330,A,5400.4506,N,00246.9492,W,5.3,22.5,170608,4.3,W,A*21

RMC: Recommended Minimum sentence.

170330: Readings taken at 17:03:30 UTC.

A: A=active or V=Void.

5400.4506, N: Latitude 5400.4506', North.

00246.9492, W: Longitude 00246.9492', West.

5.3: Speed over the ground in knots.

22.5: Bearing angle in degrees True.

170608: Date: 17^{th} June 2008.

4.3, W: Magnetic Variation.

A*22: The checksum.

Contents i.e. latitude, longitude, their respective directions, bearing angle at that point in the direction mentioned in Fig. 2 and speed limit are extracted from this RMC sentence and written in location 10 of Table 1. Same procedure has been followed for the rest of locations.

REAL TIME SIMULATION AND ROAD TEST

The simulation method used in the development was computer based simulation in which C language was used as a basic tool and the *turbo C v3.0* was utilized as platform to obtain desired output. Program written in C language' can be optimized, independent of specialized hardware [6]. The input was the real time NMEA streams received from GPS receiver through RS-232 port which were consisting of ASCII characters. First of all a database was created by travelling along the roads shown in Fig. 2, that contained information associated to those points of interest mentioned in Table 1. The flow chart representing the flow control of GPS based In-vehicle Speed limit Indicator is depicted below:

ROAD COMPLEXITIES

Performance of algorithm depends upon the immense of concentration implied towards the road structures and analysis of hazards. More extensive study about architecture of the road routes enhances the development of successful algorithm and design. Some cases about complex roads have been considered, avoidance of which can cause the failure of the algorithm.

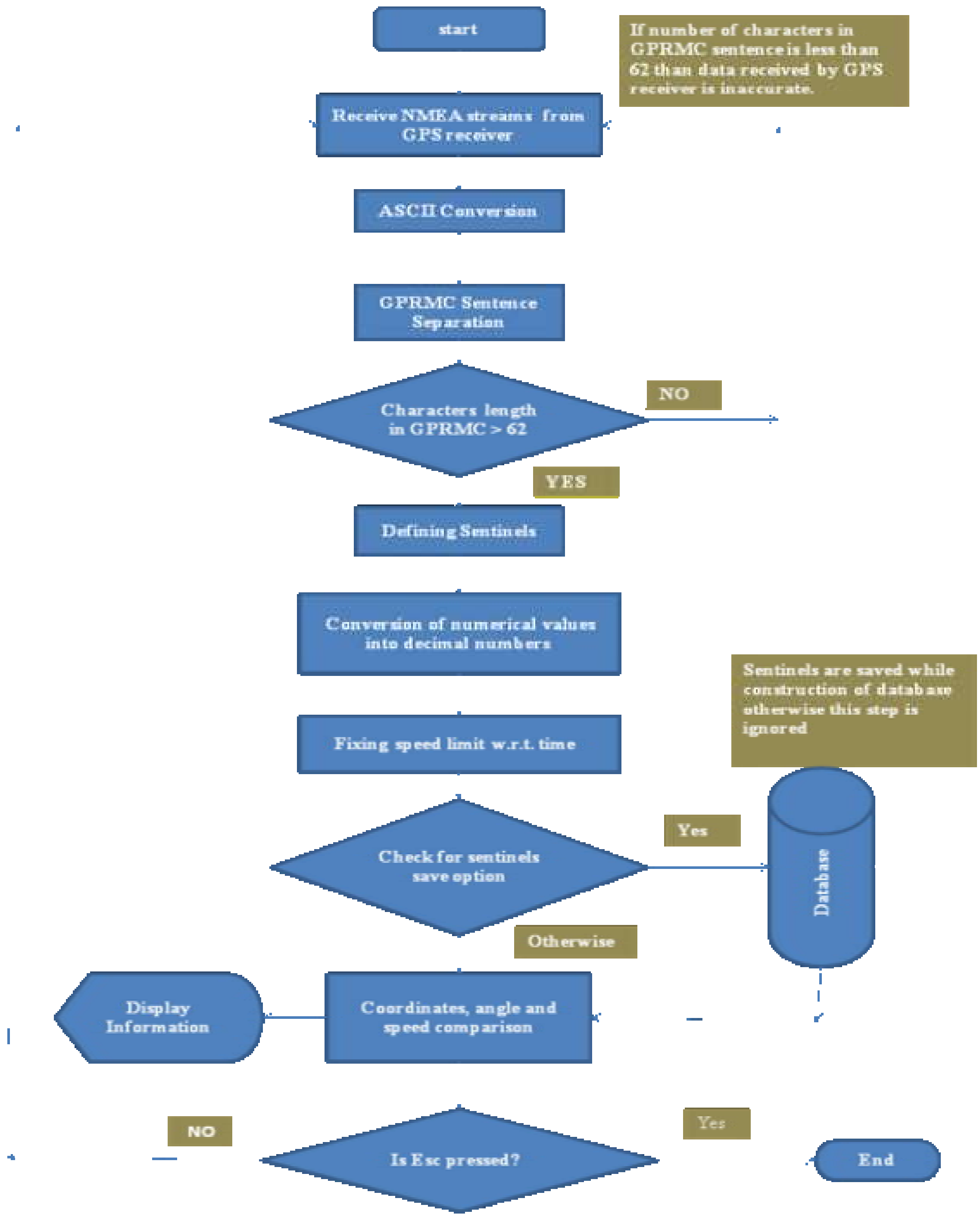
Different factors for speed choice at curves are: radius of curve, length of curvature, required speed limit, elevation of road, road width and shoulder presence [6].

Case1: Adjacent parallel roads: This happens when two adjacent roads become parallel (normally two adjacent roads are opposite having difference with an angle of about 180^0) which rarely happens. Usually, as per routine two parallel roads have distance more than 18 meter for safety purposes which can be easily handled because accuracy error of commonly used GPS receivers is less than ±5 meters. That problem occurs when a side road runs parallel with a highway for a short stretch either to join it or after leaving it, shown in the Fig. 3.

It was resolved by simple algorithm utilizing latitude, longitude and bearing angle. Bearing angle could be similar as direction is same but both latitude and longitude will be different and at least one of these must be unique. Speed limit at these roads is checked by combination of bearing angle along with both or unique one. Algorithm is given below to match locations:

```
If angle_current = angle_DB[i] and lati_current= lati_DB[i] and
longi_current=longi_DB[i]
Index_DB=i;
else
If angle_current = angle_DB[i] and lati_current= lati_DB[i]
Or    angle_current= angle_DB[i]=longi_current=longi_DB[i]
Indetox_DB=i;
```

This algorithm matches the current location with values saved in database and assigns the index of matched location at database by which speed limit can be found for that time.



Control flow of GPS based in-vehicle speed limit indicator

Case2: Roundabouts with more exits: Some roundabouts have more than four exits then it becomes difficult to decide about speed limit while driving around roundabout as navigation information changes more than once in a second where as the GPS receivers send data after one second and some older receivers like Garmin yellow sends after two seconds.

This problem has simple solution, i.e. user was informed about 80 feet before the start of roundabout and just after crossing roundabout at sentinels so that speed can be controlled easily.

Case3: Roads with consecutive curves: Another complex structure of the roads is that consist of

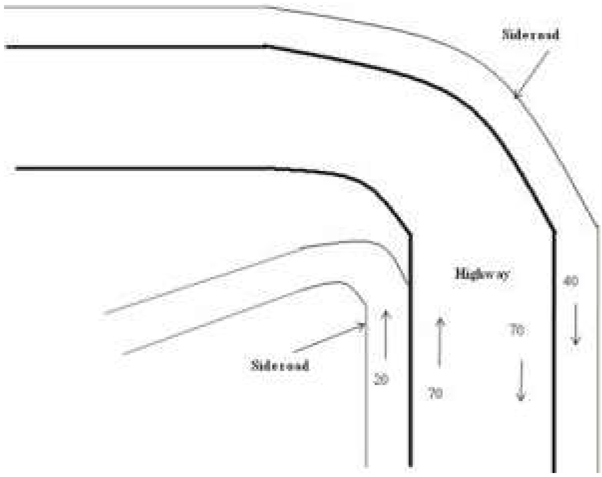


Fig. 3: Adjacent parallel roads

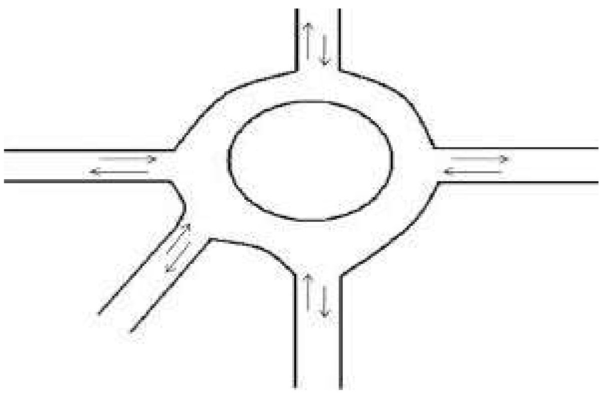


Fig. 4: Round about with many exits

consecutive curves which lie at the steeply hilly areas and inside congested city centres. Different factors for speed choice at curves are: radius of curve, length of curvature, required speed limit, elevation of road, road width and shoulder presence [7, 8].
Here come two main problems:

- Sharp changes in bearing angle.
- Sudden changes in speed limits.

Road bearing such situations is shown in the Fig. 5.

This is the case due to which hundreds of drivers get penalised daily in result of speeding. Sudden changes in angle and speed limit is tackled by adding small tolerance in bearing angle, latitude and longitude. When moving car takes a turn or crosses another vehicle then its bearing angle diverts for amount of $\pm 4^0$ from its normal bearing at specified point, same thing happens in case of latitude and longitude. In following algorithm this problem is fixed by adding tolerances to sentinels.

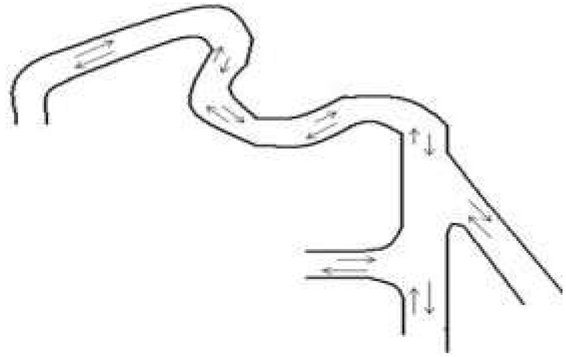


Fig. 5: Road with consecutive turns

```
If lati_current - 20 < lati_DB[i] < lati_current + 20 AND
longi_current -20 < longi_DB[i] < longi_current + 20
{
If angle_current - 4 < angle_DB[i] < angle_current + 4 Index_DB=i;
}
Else
If lati_current - 20 < lati_DB[i] < lati_current + 20 OR longi_current
-20 < longi_DB[i] < longi_current + 20
{
If angle_current - 4 < angle_DB[i] < angle_current + 4 Index_DB=i;
}
```

In above algorithm the limits assignment was done in the form of intervals and GPS receivers at least once received the GPRMC signal within this tolerance interval which was sufficient to navigate and to take decision about located sentinel.

All cases of road complexities were implemented in C language and examined by executing the simulation program (C code) to affirm the performance. The NMEA streams were manually taken as input which were received by GPS receiver and compared with already stored in database and expected functionality was accomplished successfully.

SPEED LIMIT TESTS

In order to verify the algorithm implemented in C language a simulation test was carried out at roads of Lancaster University. During the road test simulation, laptop was held along with GPS receiver in a car to observe the output and warning messages. These tests were performed at different timings by considering the peak hours as congestion time and rest of the time as regular hours for normal speed limitations. The speed limits checked for the mapped sentinels and the general present zone limit where the car was moving around. Speed limits were observed for four different conditions, which are:

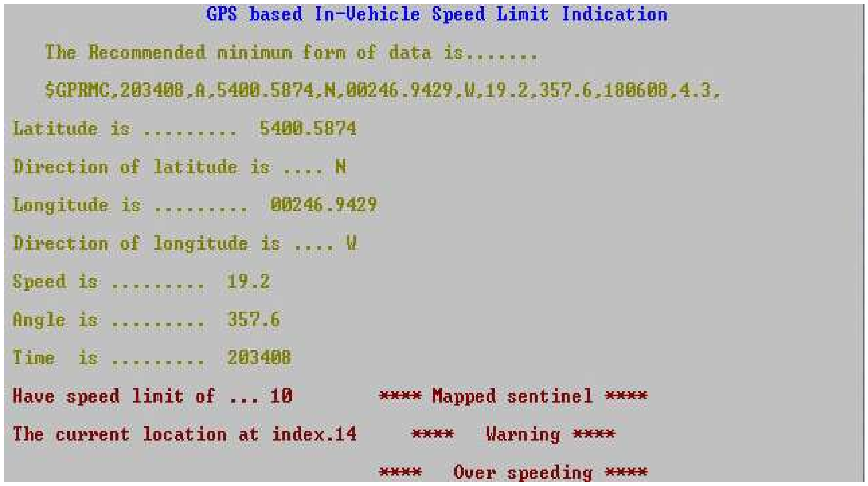


Fig. 6: Mapped sentinel normal hours over speeding

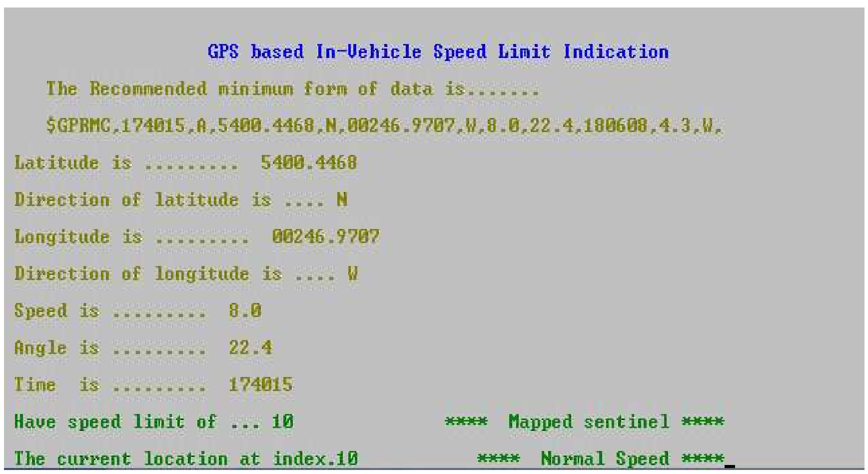


Fig. 6: Mapped sentinel congestion hours normal speed

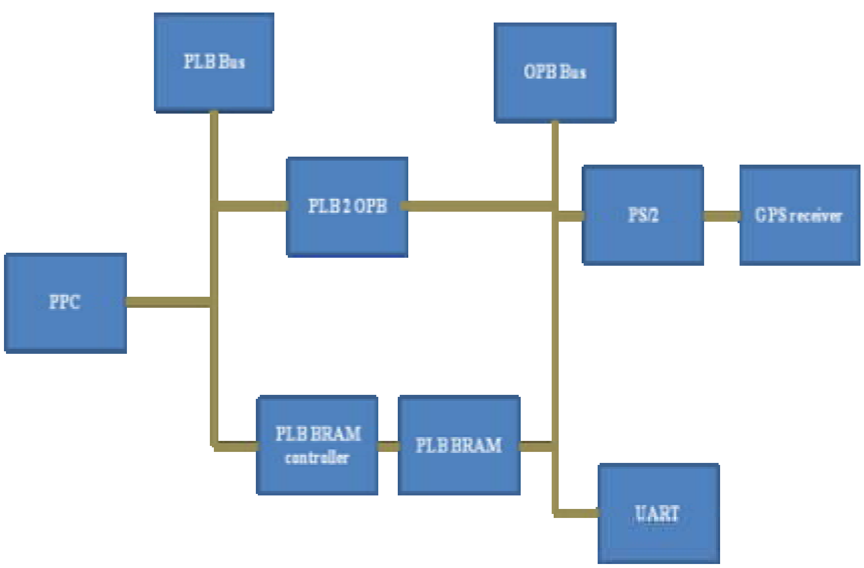


Fig. 7: Block level schematic of designed hardware

- Mapped Sentinels Over-Speedings
- Mapped Sentinels Normal Speed
- Normal Zone Normal Speed
- Normal Zone Over speeding

The output screens indicating warning and normal messages and sentinels parameters, are depicted below: At the time of displaying the warning, a beep (sound alert) was generated so that without diverting gaze, driver can be warned about speed violation and reduces the speed. This was attained by writing a simple sound command in C code that used the system speaker to produce the beep. Different intensity beeps were used according to difference between design speed limit and current speed but after test drives these were replaced with same one to avoid driver being disturbed by different sounds.

FPGA IMPLEMENTATION

The FPGA used for implementation was Xilinx Virtex-II pro. Virtex-II pro Development board provided by Xilinx consist of different electronic components help in implementing various designs. Base System Builder (BSB) was used within Xilinx Platform Studio (XPS) provided by Xilinx University Programming (XUP), to implement the hardware design on FPGA. The components and Intellectual Properties (IPs) of FPGA, used to achieve the desired results, are shown in the Fig. 8.

CONCLUSION

Sentinels were mapped on the specified points on the roads consisting of longitude, latitude, directions longitude and latitude, bearing angle and speed limit with reference to time. These sentinels were containing geographical location coordinates without graphical information that reduced the memory requirements. Moreover these sentinels were less expensive with simplified software and elementary hardware.

Although the mapping technique was simplified but there were complex road architectures. All possible problems were resolved in algorithm implementation which could be faced during driving on complex roads. Three such cases along with their solutions are included in this paper.

Simulation was performed to observe the real time behaviour of GPS based In-vehicle speed limit indicator. For this purpose an algorithm was developed which include the receiving of NMEA Sentences from GPS receiver, executing these for all processes mentioned in flow chart to achieve desired outputs display. A sound alert was generated with warning display while remained quite in case of normal speed information presentation.

Xilinx Virtex_II pro Electronics Development Kit (EDK) was used to implement the GISLI on FPGA and platform used to implement this was Xilinx Platform Studio (XPS), as XPS supports C language programming. It takes less time to market and it is easy to access hardware resources by utilizing C programming within FPGA. The mass product price is also very less for FPGA. FPGA implementation was accomplished through downloading bit streams on EDK generated by using XPS. FPGA can be modified for same or different application for unlimited number of times.

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