Monitored Intelligent Car Speed Adaptation (MISA) System

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Abstract— With the rapid increase in number of vehicles in Saudi Arabia, the traffic accident caused by high speed has become a serious health problem. Saudi Arabia is currently taking the lead in the number of car accidents in the world. Over 65% of accidents occur as a result of vehicles travelling at excess speed, which makes traffic accidents among the top five causes of death in Saudi Arabia.

To address this problem, we propose a solution, called Monitored Intelligent Speed Adaptation (MISA), which aims to enhance the driving safety through monitoring driver’s behavior and alerts him/her if any traffic rule violation has been made. The driving safety is also indirectly achieved by collecting information about vehicles’ behavior which provides researchers and traffic department with valuable data that help them in studying the violations and the problems in the roads network. This aim was achieved through developing a system of two subsystems. The first one is designed to be installed in the vehicle to inform the driver of the current street maximum speed limit while driving and alerts the driver when he/she violates this maximum speed limit. The car speed and its position on the road network are determined by analyzing the received GPS signals. Car behavior data are collected and sent to the second subsystem which is a central server that eventually collects data about registered vehicles’ behavior. These collected data can be used for providing statistics for researchers and decision makers, tracking purposes as well as keeping log for each driver that can be accessed by insurance companies.

Index Term— Intelligent speed adaptation, MISA, traffic accidents control, intervening degree, advisory systems.

I. INTRODUCTION

Encouraging or furthermore enforcing drivers to adhere to the maximum speed limits assigned for the road networks is a big concern in many countries, as violating these limits both increases the possibility of having car accidents and the severity of those accidents. It has been observed that, for example, a child death as a result of being hit by a car traveling in 40 mph has a very high probability. This probability decreases to 50% if the car is moving at 30 mph and further drops down to 5% if the car’s speed is 20 mph [3]. Another problem that is of a concern to many countries is the lack of accurate real time data about traffic violations and vehicles behavior for the researchers to build their decision upon [4]. In KSA particularly, there is an urgent need to develop a feasible solution that can be put into action as soon as possible and make an effect in the very near future.

Globally, many approaches have been followed to solve these problems. For example for the former problem humps, radars, secret traffic, deploying speed cameras were among the solution developed yet still not able to reduce the problem to a satisfactory level. Intelligent speed adaption systems, abbreviated as ISA systems, were developed as well in different levels of intervening in many countries [5] with an aim to improve the driver’s behavior while driving rather than penalizing violations. However, these systems still have the problem of restricting the driver control over the vehicle [6], taking long time to be taken into action as the case of mandatory and voluntary ISA systems [7]. In addition, they may suffer from limited effect in influencing the driver behavior such as the case with advisory systems.

As far as the authors’ knowledge, no current implementation of ISA systems has been deployed in KSA. Therefore, our solution, MISA, aims to introduce this concept in KSA while taking into account defects noticed in other countries’ experience with such systems. This is done by combining the ISA advisory system with no physical control over vehicle but monitoring the car speed remotely to increase the influencing the driver behavior positively.

As the system collects large amount of vehicles’ behavior data on the road network, it is considered a valuable source of data for researchers and decision makers interested in traffic managements and control.

MISA is multidisciplinary system that tackles many active fields of knowledge in computer science such as Geographical Information Systems, Embedded systems, Hardware, Location Based Applications, Mobile network communication along with advanced algorithmic and architectural techniques.
The rest of the paper is organized as follows. Section 2 elaborates on the problem we are tackling in KSA. Section 3 provides a literature review of the most representative ISA systems where definitions for some related terms can be found. Section 4 describes the architecture of our proposed system, MISA. Section 5 details the implementation specification of MISA. Finally, Section 6 concludes the paper and gives recommendations for future work.

II. PROBLEM IN SAUDI ARABIA

The road traffic accidents, the leading cause of death by injury and the tenth-leading cause of all deaths globally, now make up a surprisingly significant portion of the worldwide burden of ill-health. An estimated 1.2 million people are killed in road crashes each year, and as many as 50 million are injured, occupying 30 percent to 70 percent of orthopedic beds in developing countries hospitals. If present trends continue, road traffic injuries are predicted to be the third-leading contributor to the global burden of disease and injury by 2020 [8].

Saudi Arabia has the highest rate of traffic mortality and injuries compared with other countries [1, 2]. Most of the countries managed to reduce the proportion of deaths per hundred thousand people between 1999 and 2005, however, the mortality rate in Saudi Arabia has been increasing [4]. Following are some traffic accidents statistics:

- As mentioned in Saudi Safety Traffic Organization's website [15], the total number of traffic accidents was 435,264 in 1428 H, which caused 36,025 injuries and resulted in total of 6,358 traffic mortalities. Although the number of accidents occurred outside cities is far smaller than the number of accidents took place inside cities, outside cities accidents caused more death situations, as shown in Table 1. Moreover, 34.3 % of injuries happened to those who are aged between 18 and 29 years.
- "Of deaths in Ministry of Health hospitals, 81% are due to road traffic accidents and 20% of their beds are occupied by traffic accidents victims. Also, 79.2% of patients admitted to Riyadh Armed Forces Hospital with spinal injuries have sustained their injuries as a result of a motor vehicle accident." [10]
- As stated in traffic departments’ Annual Statistic Report for the year 1426 H, each day 16 people die in traffic accidents in Saudi Arabia. Also the total number of accidents was 296015 in 1426 H in which 5982 people died. This means that we have 20 death situations for every 1000 accidents. As a matter of fact, traffic accidents are the first cause of death in Saudi Arabia.
- The head of traffic department Gen. Fahad Al-Bisher said that Saudi Arabia spends 734 million riyals annually on medical care for people involved in car accidents. In addition, he said that traffic accidents cost Saudi Arabia about 13 billion riyals each year, which is expected to reach 24 billion SR in 1440 if there is no improvement in the field of traffic safety in the kingdom. [6,7]

<table>
<thead>
<tr>
<th>Number Accidents</th>
<th>Mortality Situations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Cities</td>
<td>372,724</td>
</tr>
<tr>
<td>Percentage</td>
<td>64.37%</td>
</tr>
<tr>
<td>Outside Cities</td>
<td>62,540</td>
</tr>
<tr>
<td>Percentage</td>
<td>35.63%</td>
</tr>
<tr>
<td>Total</td>
<td>453,264</td>
</tr>
</tbody>
</table>

The main cause of traffic accidents is the violation of speed limits as stated in traffic departments’ Annual Statistic Report for 1426 H. In the Riyadh annual traffic road accidents for 1427 H, the sudden unexpected movement of car is the first cause for mortality accidents, and the violation of high speed limit is the second cause [14]. Factors that contributed to this problem are as follows:

1) **Limitations in enforcing drivers to adhere to the traffic rules:** Traffic departments use many traditional methods to enforce drivers to adhere to speed limits. Examples of these methods are using humps, radar, secret traffic, and deploying speed cameras with penalties, i.e. Saher system [16], in areas that have more speeding and accidents problem. However these traditional methods do not provide satisfactory solution because: their effect is limited in space and time. Moreover, traditional ways are not flexible in terms of taking into account time of day, day of week etc. Most of the developed countries that are not suffering as much as KSA from this problem has begun seriously to look for alternative methods such as (ISA) since 1990[7].

2) **Limited number of traffic department staff:** With the rapid increase in number of vehicles in Saudi Arabia (7 million vehicles), the traffic department managed to cover this number by only 14 thousand traffic policemen including those who work within offices . This means a ratio of 1 traffic policeman for every 500 vehicles. It was supposed to serve the capital city of KSA ‘Riyadh’ alone over nine thousand policemen, while the current actual number is over a thousand [13]. This shortage of staff led to limited observation of drivers’ behavior in the road network.

3) **Absence of Speed limit signs:** From the survey we have conducted among 50 car drivers, it has shown that only 33% of them s know exactly the maximum speed limit in all different types of roads. About 90% of them have the willing to adhere to speed traffic rules if they know them.
This suggests that about 60% of drivers are ignorant regarding speed limits but are willing to adhere.

4) **Lack of traffic situation data:** the statistics about the total number of traffic mortality in Saudi Arabia is less than the reality. This is concluded from the difference between Saudi Arabia's definition of traffic mortality, which is dying in crash location or during transition to a hospital [14], and the World Health Organization's definition which is dying immediately or within 30 days as a result of the crash [8]. Furthermore, most of the countries that have succeeded in reducing the percentage of deaths resulting from traffic accidents have been provided with a comprehensive and accurate data on the percentage of traffic violations and accidents so that the researchers and traffic engineers can solve this problem. So far, In Saudi Arabia, there is no central database for violations and accidents statistics for the whole country. Moreover, most of the studies were based on incomplete or outdated data [4].

III. RELATED WORK

Over the past few years, there has been a considerable enhancement in the driving safety. Enforcing the driver to adhere to the speed limit of the vehicles has been of great interest around the world. In Franc 1982, a new method appeared in order to reduce the speed limit. This method was called ISA or (intelligent Speed Adaptation) [7]. ISA is the generic name for advanced systems in which the vehicle “knows” the speed limit and is capable of using this information to give feedback to the driver or limit maximum speed [10]. In this section, categories of ISA systems will be presented. This will be followed by listing the technologies used in implementing ISA systems and, finally, comparison between the most well-known ISA systems in the market is presented.

A. **Classifications of ISA Systems**

ISA systems can be categorized by their intervening degree into [7]:

- **Advisory:** it is able to inform the driver of current speed limits and gives the driver a feedback through a visual or audio signal.
- **Voluntary:** ISA increases the upward pressure on the accelerator pedal in case of exceeding the speed limit. However, it is possible to override the voluntary system by pressing the accelerator harder.
- **Mandatory:** ISA prevents any speeding over the allowed speed limitations, for example, by reducing fuel injection. Also, ISA systems can be differentiated in terms of the flexibility of assigning speed limits [7, 9].
- **Fixed:** The vehicle driver is informed by the posted maximum speed limit of the current street.
- **Variable:** The speed limit is more particularly assigned taking into account special characteristics or needs of some locations, in which lower speed limit implemented, for example around pedestrian crossing or the approach to sharp horizontal curve.

- **Dynamic:** The speed limit in this system is updated over time as well, in which lower speed limits are implemented because of network or weather conditions, for example to slow traffic in fog, or around major incidents.

The first ISA appeared in France was not really intelligent speed adaption, because the system did not automatically set the correct speed limit, instead drivers had to set limiter themselves and, rather like a cruise control, they could set it as they chose. This was followed by around 10 years gap until research on ISA was resumed in Sweden in the early 1990s. This was followed by series of projects in Sweden culminating in the large scale trial of 1999 to 2001, when there were close to 5000 ISA- equipped vehicles on Swedish roads. Most of these vehicles were equipped with an advisory ISA, but few hundred were Voluntary. Britain began its national research in 1997 to 2000 with External Vehicle Speed Control project [7].

B. **Technology used to implement ISA systems**

In intelligent speed adaption, the vehicle needs to know its location. There are two common approaches for this:

- **Use roadside beacons** attached to roadside or other roadside infrastructure, such as lampposts. These beacons transmit the information regarding the road posted speed limit to the vehicle, and then if the vehicle exceeds this limit the onboard device triggers the wringing and/or limiting system. For a beacon system to operate, a central control system needs to exist. This central system defines the attributes for each beacon and downloads this information into each beacon using a mobile communication.

**Advantage of using beacon:**
- The beacon system operates as soon as the vehicle passes it, with a little delay.
- The use of mobile communication allows speed limit to be changed, e.g. in the event of roadwork.

**Disadvantages of using beacon:**
- Maintenance cost.
- Deployment cost since operating beacon based ISA in the whole city needs installing a beacon in each road link.

- **Use of global positioning system (GPS),** this approach has been adopted most widely in ISA trials. With GPS, we need digital road map on the vehicle board which contains the speed limit as an attribute for each link in the road. As soon as the vehicle navigation component realize that the vehicle is traveling in the particular link of the road, the ISA system will know the speed limit and triggers by warning and/or limiting system if the vehicle exceed this limit. This approach needs a way for updating the maps, for example, in case of changing road speed limit or adding...
new roads. Changing vehicle maps can be done by using digital radio network such as third generation mobile phone system (3G).

**Advantages of using GPS:**
Low deployment cost compared with beacon system.

**Disadvantages of using GPS:**
The limitation of GPS technology is the loss of signal in built-up area.

C. **Comparison between the most representative ISA systems**

Following are three representative ISA systems with a brief description for each of them.

- **Vehicle Information and Communication System (VICS) in Japan:**
  VICS uses the infrared beacons to transmit traffic information from roadside to vehicle of which almost 8 million on-board units have been sold. System testing has been carried out by the National Police Agency of Japan [13].

- **Continental : Active Distance Support (ACDIS):**
  ACDIS is a new system to support the driver in the longitudinal guidance of a vehicle combining distance sensors and Force Feedback Pedal as shown in Figure 1 [14].

- **Limit Advisor (Imita):**
  Imita is a Swedish active speed assistance system. As it can be seen from Figure 2, when the speed limit is exceeded, a resistance from the accelerator is felt, which informs the driver that he has reached the permissible speed [4].

Table 2 presents a comparison between the above mentioned systems in terms of the number of vehicles that used the system, the used technology, the main functions, advantages and disadvantages, cost, and deployment cost.

D. **Best ISA intervening degree**

The best prediction of accident reduction was that the fitting of a simple mandatory system on all vehicles, with which it would be impossible for vehicles to exceed the speed limit, would save 20% of injury accidents and 37% of fatal accidents. A more complex version of the mandatory system, including a capability to respond to current network and weather conditions, would result in a reduction of 36% in injury accidents and 59% in fatal accidents [10].

A. Many studies have shown the effectiveness of the ISA system in improving drivers’ adherence to speed limits. On the other hand, another studies focused on the drivers’ opinion of such system, these studies show that [5]:

- The Mandatory system was not accepted by most of the drivers while they approved the Advisory system more, because they felt that they still had control over their cars.
- The Mandatory system was considered very frustrating and dangerous. The drivers were concerned about when there would be a need to exceed the speed limit to avoid an obstacle. They also thought that the Mandatory system expected to cause more rear-end collision because it makes other car drivers drive very close.
- Moreover, even if Mandatory system is effective in managing the speed, they mentioned that they probably would not use it if they could switch it off.
- Finally, about the drivers’ willingness to pay for such systems, the Advisory system got (54%), where the Mandatory system got (45%).
<table>
<thead>
<tr>
<th>Project</th>
<th>VICS in JAPAN</th>
<th>Limit Advisor (Imita)</th>
<th>ACDIS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>Advisory</td>
<td>Advisory</td>
<td>Mandatory</td>
</tr>
<tr>
<td><strong>Number of vehicles</strong></td>
<td>------</td>
<td>4500  280  400  284</td>
<td></td>
</tr>
<tr>
<td><strong>Used technology</strong></td>
<td>Infrared beacons (on road)</td>
<td>GPS</td>
<td>Distance sensors</td>
</tr>
<tr>
<td><strong>Main Functions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Drivers can get in advance the traffic information such as congestion.</td>
<td>• Informative ISA.</td>
<td>• Driver support in distance control and in speed control (Cruise Assistance, Cruise Control).</td>
<td></td>
</tr>
<tr>
<td>• The system can display a simple deformed pictorial map instead of a digital map.</td>
<td>• A light and auditory signal.</td>
<td>• Distance determination to heading vehicle through cost effective sensor technology.</td>
<td></td>
</tr>
<tr>
<td>• It features voice recognition operation and synthesized voice announcement of text data.</td>
<td>• Presented if speed limit exceeded.</td>
<td>• Counterforce at the accelerator pedal when driver falls below the safety distance to ahead driving vehicle. Driver receives a feeling for the “virtual bumper” through the feedback of the accelerator pedal.</td>
<td></td>
</tr>
<tr>
<td><strong>Advantages</strong></td>
<td></td>
<td>By using GPS signals, Limit Advisor can achieve accuracy of 10 meters.</td>
<td>• Counter force at the accelerator pedal when driver falls below the safety distance to ahead driving vehicle. Driver receives a feeling for the “virtual bumper” through the feedback of the accelerator pedal</td>
</tr>
<tr>
<td>• Infrared beacon can provide information about highways and ordinary roads as far as 30 km ahead, and 1 km behind the car.</td>
<td>• The system's lifetime is shorter than the vehicle's lifetime.</td>
<td>• System can be overruled by driver.</td>
<td></td>
</tr>
<tr>
<td>• The navigation equipment can receive signal from running direction within 3.5 m from each beacon.</td>
<td>• The counter-pressure is the default state of the limiter and weather this is safe when the system is not working properly is debatable.</td>
<td>• Force Feedback Pedal can Clearly be associated with longitude guidance of a vehicle.</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td></td>
<td>• Not all vehicles are suitable for installation of the Imita system.</td>
<td>• Display of warnings (e.g. critical driving Situations).</td>
</tr>
<tr>
<td>• The infrared beacon must perform all processing and send the route while the in-vehicle unit is within the communication zone.</td>
<td>• The digital map capacity was too small.</td>
<td>• No distraction from traffic situation.</td>
<td></td>
</tr>
<tr>
<td>• Inaccurate data logging.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Low cost</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Deployment cost</strong></td>
<td>High</td>
<td>Low</td>
<td>n/a</td>
</tr>
</tbody>
</table>
Our approach is to use the features available in ISA 'dynamic advisory system' to guarantee drivers acceptance. Therefore, the driver will not feel frustrated for being restricted on controlling their vehicle. Moreover, they are not going to worry about the urgent situation where the driver might need to exceed the speed limit in order to avoid a road hazard. On the other hand, to encourage the driver to adhere to the speed limit, the system keeps sending reports about speed violation after a specified duration and/or frequency and gives the driver a chance to cancel this report by slowing down [6].

IV. PROPOSED SYSTEM REQUIREMENTS

In this section, user categories of our proposed ISA system are listed, followed by the expected requirements for the proposed ISA system together with its dependant components requirements, i.e. Tracker and Traffic Department.

A. User categories

We have the following categories of system users:

- **Drivers**: interact with the system through a simple interface of in-car device with limited tasks such as entering user name and password, view numbers and symbols indicating maximum speed limit and violations alerts.
- **Tracker (householders)**: create new users and modify users’ accounts. They will also interact with the system through SMS messages and emails.
- **Traffic Department Employees and Researchers**: access the system through a website and make different queries regarding cars situation and view information regarding traffic current situation.

B. ISA System Requirements

The system has two modes: setup mode and navigation mode. When the car is stationary, the setup mode is on. In this mode, the administrator can control the drivers’ profile, car specification and the trackers. In addition, the drivers can only logged in to the system in this mode. The navigation mode works during car movement to detect the speed and direction violation.

**Setup Mode**:

1. When the system is switched on, a dialog screen prompts the driver to enter the username and password. Also, the username and the password cannot be entered unless the car is stationary. If the driver starts moving the car without entering the username and the password, the following actions can happen:
   1.1 The system gives alert telling the driver to stop the car and log in.
   1.2 If the driver is not logged in after X seconds, the system alerts the tracker that the car is moving while the driver is not logged in.
   1.3 If the driver try to log in while the car is moving, the system displays message informing the driver that the signing in is not allowed unless the car is stationary. (For safety reason).
   1.4 When the driver enters the username and the password the system verifies the identity of the driver.

2. In the logging in screen, the driver can change his/her password by choosing "Change Password" label so, the system displays a new screen that asked the driver to enter the old password, the new one and the verification of new password.

3. If the logged in driver was the ISA system administrator, the interface would be slightly different giving the administrator the authority to access the control panel and the Screen displays the labels "Add User", "Edit User", "Car characteristic " and "Add Tracker". By choosing each label he/she can do the following:

   3.1 "Add User": By choosing this command, the system checks whether number of accounts have reached the maximum limit. A new screen is displayed prompting the administrator to enter the new username, password and password verification. If the user enters the new username, the system checks if it is used before. If so, the system displays message "the username used by another one.. please enter new username again". Then a "User Profile" screen, "Reporting Options" screen and "Tracker" screen are displayed sequentially:
   3.1.1 "User Profile" to add the user ID, name, age, gender, nationality and the type of driving licenses.
   3.1.2 "Reporting Options" to enable the administrator to specify reporting options by checking next to desired options:
     - The start and the end of car trip (how to specify this distinguishing end of the trip from usual stops).
     - Estimate fuel consumption (per trip, per day, per working hours, per month etc). (Which factors have effects on the fuel).
     - Detected Speed violation including specifying the maximum speed when there is no assigned maximum speed limit.
     - Wrong direction detection.
     - If the vehicle was located in prevented link in terms of place or time.
     - The driver shuts the system down.
     - The driver starts moving the car without entering the username and the password.
   3.1.3 "Select Tracker" to choose the tracker who receives the reports from tracker list.
   3.2 "Add Tracker" to add the tracker information (Phone number and e-mail) who receives the reports from the car. The system first checks if the tracker was entered before. Each driver has one or more tracker and each tracker has one or more phone number and e-mail.
   3.3 "Edit User" once the administrator choose this command the user list of this car is displayed followed by two buttons, "Edit" and "Delete". So, if the administrator highlight any user then press:
3.3.1.1 "Delete" a dialog message is displayed to confirm the deletion process.
3.3.1.2 "Edit" the user profile screen is opened for change.
3.4 "Car Profile" to add the car information (car number, type, fuel etc.). So, if the car type was 'truck', then the speed limit will be 80.00 km/h even if the speed limit in particular road is more than 80km/h. Also, trucks can not be on the left side of the road and run all the time.

**Navigation Mode:**

4. The system keeps reading GPS signals to determine the car's position (longitude, altitude, and latitude), car speed and car directions.
5. Using the position determined by the GPS, the system retrieves the nearest link to the car to decide which street the car is on. The system will refresh the speed limit displayed on the monitor if any change happened.
6. By comparing the maximum speed allowed in the current link with the car speed, the system decides whether there is a speed violation and take the following actions:
   6.1 The system gives voice alert informing the driver of the speed violation.
   6.2 If the driver does not reduce the car speed after x seconds or minutes (depend on acceleration), the system reports to the tracker.
   6.3 If the car speed is slow by X% than the speed limit and the car in the highway, a traffic jam is detected.
7. The system identifies the car direction and compares it with the link direction. If the system detects a vehicle movement in the opposite direction, it takes the following actions:
   7.1 The system gives voice alert informing the driver of direction violation.
   7.2 If the driver does not correct the car direction after x seconds or minutes, the system reports to the tracker.
8. The system will not detect the car direction if the car speed was zero.

**C. Tracker requirements**

1. The tracker receives automatic reports and alerts regarding driver behavior through mobile SMS and Email. Type and frequency of reports received depend on driver "Reporting Options".
2. The tracker is able to generate a set of queries and send them to the server which in turns either process these queries and send the results back to the tracker or send an order to the ISA system to process the query and send the results back to the tracker. These queries are sent and received through SMS or email messages. The following is a list of queries the tracker is able to generate
   2.1. Car current position: The server in this case orders the ISA system to process this query and send the results back to the tracker. The ISA system constructs a message containing the user position description. This description includes the city name, road name, nearest intersection, district name.
2.2. Queries asking for reports for:
   2.2.1. Trips of the (last month, week, …etc).
   2.2.2. Driver adherence to traffic regulations over the past (month, week, … etc).

**D. Traffic department requirements**

The system will provide the following facilities for the traffic department through a website.
1. Creating a user profile for each traffic department employee.
2. Active statistics display and alerts: This facility allows traffic department to be informed with any anomaly detected in traffic.
   2.1. A dynamic map is displayed showing any abnormal situation of these listed below.
3. If the system detects x number of cars in specific area moving in a speed less than the normal level, it alerts the traffic department through their interface that there is a possibility of Traffic jam.
4. If the system detects extreme situation of speed violation, it alerts the traffic department (we mean by extreme that the number of cars causing the violation and the percentage of exceeding the maximum allowed limit is large enough to alert the traffic department).
5. If the system detects extreme situation of direction violation, it alerts the traffic department (we mean by extreme that the number of cars causing the violation is large enough to alert the traffic department).
   5.1. The traffic department official is able to obtain more information about the current abnormal situation (by rolling over the map and pressing).
   5.2. If anomaly was detected, the system alerts traffic department officials through the website and SMS messages. The alert message contains type, time and location of anomaly along with a certainty degree.
6. Queries: the traffic department officials are allowed to issue a set of queries by defining conditions to the following variables and getting results.
   6.1. Selecting spatial property
      • select from a list of road names
      • select from a list of districts
      • select from a list of road classes
      • select part of a road – two points (this needs interaction with map)
      • select from a list of cities
      • select from part of a city – polygon area (this needs interaction with map)
   6.2. Select temporal property
      • Year (1 year, from year X to year Z, all years)
      • Month (1 month, from month X to month Z, all months)
      • Day
      • Time (hours and minutes) (time unit larger than alerting system)
6.3. Select class of drivers
IV. PROPOSED MISA SYSTEM

MISA proposes a new method to enhance the driving safety. The system’s goal will be achieved through developing a system of two parts: MISA Client and MISA Server. **MISA client** is designed to be installed in the vehicle as an embedded system. It informs the driver with the maximum speed limit considering low speed zones and alerts him visually or vocally when violating this limit (Dynamic Advisory ISA system). Furthermore, if the system detects any violations of speed limit (for specified duration and/or frequency), it will send a report, after giving the driver a chance to cancel reporting by slowing down, to the central database in the second part of the system **MISA server** with sufficient information such as the car location and the violation time.

While the database stores all these reports, the analyzer component in MISA server converts these reports into statistical results, drawn on the maps as a live modeling of the traffic speed violation crashes. Crashes’ data can be inserted immediately by traffic department employees in the accident site through a mobile interface available for them. Moreover, MISA server allows researchers and government workers to query its large and rich database through a user friendly interface that allow the user to specify certain values of certain violations’ attributes such as violation type, degree, driver age, nationality, car type, violation location and time to get the needed specific statistics. The query results are displayed on tabular format and shown with color code on the map. MISA system components are shown in Figure 3.

A. MISA System Architecture

MISA Client subsystem has been designed and developed to be installed in the vehicle as an embedded system. It consists of four components: GPS Receiver, GPS Handler, MapMatcher, and Car Behavior Analyzer. The GPS Receiver component receives GPS signals from satellites. The GPS Handler component finds the car location and speed information using received signals. Then, the MapMatcher [11] component tries to match the car position to the road network digital map. The Car Behavior Analyzer keeps monitoring the driver adherence to the speed limit by using information provided by the other components and generates alerts and reports in case of violation along with recording car behavior data in a log file. Moreover, it sends this log file when it detects an internet connection to the server central database. Eventually, a large amount of data about vehicles’ behavior for a large number of vehicles is collected and analyzed in the Life Analysis component and The Traffic Query Component to provide the required statistics.
B. MISA System Implementation

As shown in the previous section, MISA consists of two main subsystems, the MISA Client, is installed in ebox 4300 which is an embedded device, inside the vehicle. The ebox4300 device is connected to Garmin GPS receiver. While the car is moving, the GPS receiver keeps receiving GPS signals, NMEA messages, from GPS satellites. MISA client application processes the received NMEA messages to extract car position and speed. Each time data is received from the GPS receiver, the software performs long processing to match the car position to the correct link on the street network. MISA then observes the car behavior in terms of its compliance to the maximum allowed speed limit of the current street. Furthermore, if the system detects any violations of speed limit (for specified duration and/or frequency), it will send a report to the central database with sufficient information such as the car location and the violation time etc. In addition, this system detects schools and hospitals zones and alerts the driver in order to slow down. Here, the second subsystem of MISA appears which we called MISA Server. While the database stores all these reports, the analyzer component of the software converts them into statistical results, drawn on the maps as a live modeling of the traffic violation of speed and crashes. Moreover, MISA server allows researchers and government to query its large, rich database through a friendly user interface that allows the user to specify certain values of certain violations attributes. The query results are displayed on tabular format and shown with color code on the map using Microsoft Virtual Earth and rendered by SQL Server Spatial Engine. Streets layer has been displayed using software tool called Simplovation. Figures 5 and 6 show the technical components of both MISA Client and Server, respectively.

C. Walkthrough the implemented System

This section gives an overview of how the MISA implementation is done. The client part has been developed as a windows application; also, object oriented technique is used to facilitate the implementation of ISA. The server host is presented in the form of the tracking website and also has an application that allows the tracker to enter the settings. Both the application and website can access the same database. Following are the steps MISA implemented system execution.

MISA Client:

1. When the driver switches the vehicle key on, the system will operate and a dialog screen prompts the driver to log in by choosing the username from a list and entering his four digits password.

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1 NMEA (The National Marine Electronics Association) message: is a combined electrical and data specification for communication between marine electronic devices such as autopilot, GPS receivers and many other types of instruments. It has been defined by, and is controlled by, the U.S.-based National Marine Electronics Association[11].
2. The system will display to the driver the speed limit in the current street and refresh the displayed speed limit if any change happened.

3. By comparing the maximum speed allowed in the current street with the Vehicle speed, the system decides whether there is a speed violation and takes the following actions:
   3.1 The system gives voice alert informing the driver of the speed violation.
   3.2 If the driver does not reduce the Vehicle speed after X seconds or minutes (depend on acceleration), the system reports to the server.

4. If the vehicle speed goes down in places where there is no traffic light or stays slow for long period of time near traffic light area, the system sends traffic jam suspicion to alert the server.

5. If the vehicle is in schools zone and during school run times (rush hours), the system asks the driver to slow down because there might be students in the area.

6. The system reports to the server if the driver drove on a forbidden road (such as a truck moving on the highway at 2 p.m.) or if the driver is driving out of safe areas determined by the tracker.

**MISA Server:**

Figure 10 shows the home page which contains a brief description of the MISA website and its functionality.

The tracking system is a private webpage shown in Figure 11. It is only opened for the owners of ISA system (tracker) and it needs an account.

The page shown in Figure 12 is opened when the tracker decides to create an account in the MISA system. In fact, it is a form for MISA to get the needed information.
The page shown in Figure 13 presents the features of the MISA system.

Fig. 13. MISA system features

The MISA website provides both Live Alerts and Offline Queries services in the Traffic Analysis option:

1. **Live Alerts**: about live abnormal situations through active statistics displayed on a dynamic map or tables as following:
   1.1- If the system detects a number of Vehicles in specific area moving in a speed less than the normal level, it alerts the traffic department through their interface that there is a possibility of Traffic jam.
   1.2- If the system detects extreme situation of speed violation, it alerts the traffic department (we mean by extreme that the number of Vehicles causing the violation and the percentage of exceeding the maximum allowed limit is large enough to alert the traffic department).
   1.3- Users are able to obtain more information about the current abnormal situation (by rolling over the map and pressing).

A screenshot of Live Alerts service is shown in Figure 14.

2. **Offline Queries**: about the violations that happen on the streets network. The results of these queries give statistics about jam, speeding and other violations. Upon these results, researchers and traffic employees can build their decisions and conclusions. The results are displayed on both tabular form and with color code on maps. They can control many variables in the query to get the needed specific results. Queries are controlled by defining conditions to the following variables: violation type, driver class, Road class, and time for violation that he interested in. Screenshots of query specification are shown in Figures 15, 16, and 17.
By clicking on the Show Query Result button, the Query results are displayed in table, as shown in Figure 18, and virtual earth map as shown in Figure 19.

VI. CONCLUSION

By making use of Advisory ISA and the monitoring influence, we expect that MISA can improve the driving safety in Saudi Arabia and other countries that suffer from high traffic accidents. This is achieved by being a convenient and feasible solution that contributes significantly to encouraging drivers to adhere to the speed limits as well as being a valuable source of road network situation data. It can be deployed in the near future if approved since no much comprehensive long-term testing need to be carried out for the advisory ISA.

The future work for MISA system lies in:

a) ISA part (in car)
   1- Enhance Map matcher algorithm quality.
   2- Make Maximum allowed speed dynamically depends on both place and time so lower speed allowed during bad weather or school runtime.
   3- Connect Streets layer to Traffic light layer to get more accurate information about traffic.
   4- E-box software should be connected with vehicle computer in order to get its current speed which should be in this way accurate 100% without the need to the GPS computations.
   5- Warning driver in case of expected accidents.
   6- Facilitate help desk call in case of emergency.
   7- Facilitates communication between driver and private sectors.

b) Server part
   1- Real Time Tracking and Traffic representation and Analysis.
   2- Interactive Query by specifying area and characteristic in map.
   3- Improve Communication Security between ISA sub Systems.
   4- Analyze Jam and Accidents, drifting, and pass over other vehicle.
   5- Improve traffic interface in order to make it compatible with mobile browser so data could be uploaded to server through mobiles on time of accidents.
REFERENCES


