A Review on Advances in Intelligent Speed Adaptation Techniques

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Abstract— Intelligent speed adaptation (ISA), also known as alerting, and intelligent authority, is any system that ensures that vehicle speed does not exceed a safe or legally enforced speed. In case of potential speeding, a human driver can be alerted, or the speed reduced automatically. Many studies and experiments have been done in this field and has resulted in fewer accidents and casualties along with reduction in fuel consumptions. Countries like USA, UK and Canada have already started using these systems for efficient transportation system.

Keywords: Intelligent Speed Adaptation (ISA), ITS

I. INTRODUCTION

Road safety is a foremost important concern regarding transportation. Intelligent speed adaptation (ISA), is a system that ensures that vehicle speed does not exceed a safe or legally enforced speed to prevent accidents. In case of potential speeding, a driver can be alarmed and alerted, or the speed can be reduced automatically. Intelligent speed Adaptation System uses information about the currently travelled road to determine the required speed. Also these fast, revolutionary developments within the realm of automated transportation vehicles like the Ehang184, no passenger, no pilot drone, and Google's driverless car are rapidly becoming integrated into our everyday environment. Relying on manual systems and methods to ensure safety and order will not meet the needs of our rapidly changing transportation landscape. Transportation training systems that can think steps ahead for us will help and assist us for our safety and pleasant driving experience.

The paper is organized in the following manner. Section II introduces the various types of Intelligent Transportation Systems (ITS) currently in use around the world. Section III discusses these ITS in detail. In Section IV we have attempted to summarize the same and have discussed the problems and challenges faced by these systems followed by future directions/implementations. Section V is the conclusion.

A list of previous works can be found in Zhang et al. (2011) and Qureshi et al.(2013).

ITS can broadly be categorized into two types. Intelligent Infrastructure Systems and Intelligent Vehicle Systems.

II. ITS AROUND THE WORLD

A. Africa

Ebot et al. (2016) conducted an experiment in Africa to evaluate the speeding distributions, speeding frequencies, speed percentiles, mean speeds, and the statistical relevance of key metrics. They found that the auditory intervention has a clear impact on speeding behaviour, both when applied at an audible level that can be drowned out by a radio, and even greater impact at a loud level. Drivers tend to ignore the advised speed and usually are inclined towards speeding. It was observed that the loud system was more effective showing significant differences compared with typical driving behaviour on the evaluated route, the preceding soft buzzing system. Later a ISA activation was done sequentially, beginning with the soft buzzing system, followed by the loud buzzing system.

Changes in speed due to the loud buzzing system were significant and it was more effective at improving mean speed in all vehicles compared with the pre-ISA and soft buzzing periods respectively. For each taxi, reverting to normal behaviour can be observed.

B. Asia

1) Sri Lanka

C Perera et al. (2017) developed an app to reduce the number of accidents. The app aids drivers to avoid excessive speeds. The app was tested on roads of Sri Lanka. According to the user evaluation results, the majority of the test drivers (80% of light-motor vehicle test drivers, 50% of heavy-motor vehicle test drivers and 40% of tricycle test drivers had experienced the application as very effective, and test drivers of vehicles of all types report a positive judgment on application effectiveness. A minority of the heavy-motor vehicle test drivers (10%) and tricycle test drivers (20%) had experienced the application as ineffective.

2) China

C. Wang et al.(2007) performed simulations on the VISSIM simulator. The road used in the simulation was a part of real-world traffic network of SanFeng Road of Baoding, China which consists of 4 links and 2 intersections. The goal of their Intelligent Speed Adaptation system was to always keep the vehicle running under the speed limit. They observed that as they increased the proportion of the vehicles equipped with ISA the Mean Speed, Speed Standard Deviation and Relative Accident Rate decreased. This was all theoretical results and further could be tested in a real environment.

O.M.J. Carsten and F.N. Tate, tested ISA system and made prediction of accident savings along with estimated costs and benefits of nationwide implementation. They proposed three variants of ISA system. Each having different levels of intervening (permissive nature). They used the equation: $y = 0.0139x2 + 0.0140x$, where y is relative risk and x is speed difference of a vehicle from mean speed in mph. The best prediction of accident reduction was that the fitting of a simple mandatory system (specific speed limit) would save 20% of injury accidents and 37% of fatal accidents. There was a more complex version of the mandatory system which was capable of responding to current network and weather conditions which would result in a reduction of 36% in injury accidents and 59% in fatal accidents.

Sven et al.(2007) conducted an experiment where thirty-four cars and three buses were equipped with the "active accelerator pedal". When the vehicle starts to exceed a specific speed limit, a resistance in the accelerator is activated and the pedal becomes stiff. [4]This configuration has some drawbacks. Feedback is only active when the driver's foot is on the accelerator. The driver is able to override the feedback upto quite an extent. Also the vehicle

will be able to over speed on downward slopes. The drivers used the systems voluntarily, because they noticed that the system assisted them well in upholding the speed limits and provided for comfortable and relaxed driving.

3) Japan

Matsuo et al.(2017) conducted a study where they selected 48 drivers who live in Zone 30 in Japan and who used to drive at least three times a week. Their vehicles were equipped with Advisory ISA installed in their smartphone which monitored driving speed and coordinates using GPS. The tests were carried out for a total of 10 months with different ISA types like Advisory, Voluntary, and Mandatory. It was observed that acceptance rate was greatest for advisory ISA and decreased for voluntary and then for mandatory respectively. Acceptance of Advisory ISA being highest maybe due to ease in violating the specified speed limits.

4) USA

United States of America: ITS is coordinated through Research and Innovative Technology Administration wing (RITA) of U.S. Department of Transportation in the country. Along some federal and private agencies, RITA focuses on ITS initiatives like Telephonic Data Dissemination, IntelliDrive, Next Generation 9-1-1, Cooperative Intersection Collision Avoidance Systems, Congestion Initiative, Integrated Corridor Management Systems, Clarus Initiative, Emergency Transportation Operations etc. and few are discussed as below:

- IntelliDrive, with the help of wireless technology, allows communication among vehicles, infrastructure and mobile devices of travellers.
- Cooperative Intersection Collision Avoidance Systems deals with enabling cooperative communication systems to avoid crash problems at junctions and intersections.

5) Dubai

Middle East has been banking heavily on ITS for its fastest growing transportation sector in the world since 2001. The first phase of world's most refined ITS project was started by Dubai municipality that would facilitate rapid urban population growth and allied urban needs. Cohesive strategies have been planned as part of this mega project, which includes construction of new roads, interchanges, provision of public transportation and road network strengthening. The features of the ITS in Dubai are as follows: • Traffic jam alerts to vehicle drivers to alter the route.

- Diversion of inconvenience free normal flowing traffic from the lane having accident.
- Automated feasible changes in speed limits in the case of accidents or bottlenecks.
- Execution of pre-analysed and verified transportation management plans along traffic police.

6) Canada

Canada: Canada is the first country to introduce ITS. Along with US, Canadian government has developed Border Information Flow Architecture (BIFA), a technology based ITS solution, for simplified border crossing process. The ITS architecture of Canada's user services has following functions:

- Traveller Information Services, consisting mute guidance and navigation.
- Traffic Management Services.
- Public Transport Services.
- Emergency Management Services.
- Vehicle Safety and Control Systems.

Few ITS projects have been implemented in Indian Metros and cities like Delhi, Ahmedabad, Bangalore, Chennai, Pune, etc. All these various projects have individual nature. They focus on limited functions of ITS like traffic signal management, organized parking management, public transportation management and highway toll collection centres. Most of these projects are just pilot projects and are in primary operating stages for future large-scale implementation.

7) India

Few examples of existing ITS practices in India:

Chennai: Chennai has implemented Advanced Traffic Management System. It consists of Automatic Traffic Control system, with the help of Traffic Regulatory Management System (TRMS) which helps to observe and adjust traffic flows without interference. TRMS compromises of putting up a complete monitoring system using surveillance cameras for traffic rules violators, especially at junctions. Also FM radio is used to transmit crucial information about road blockages due to extreme weather, traffic jams etc in Chennai.

Mumbai: Mumbai has implemented Area Traffic Control Project that deals with management of traffic flows at major junctions. Technological help is also taken from latest gadgets like, accelerometer guns, radar sensor, etc.

Bengaluru and Hyderabad: A project has been deployed in these cities where real-time traffic scenario of major intersection and its secondary connector roads can be obtained via internet. A real-time feed which is updated every 15 seconds is available 24 by on an internet portal. In addition to this road users and motorists get updates for traffic jams and restricted access via SMS based systems. Prior registration is required to avail these updates for free.

New Delhi: 'The Traffic People' in 2009 was launched in Delhi which provided real time traffic conditions and updates of in-and-around New Delhi. The project provided traffic conditions during morning and evening peak hours of selected locations. A plan to initiate an SMS service with monthly subscription charges was planned but failed due to poor response and least interest from users and unavailability of data.

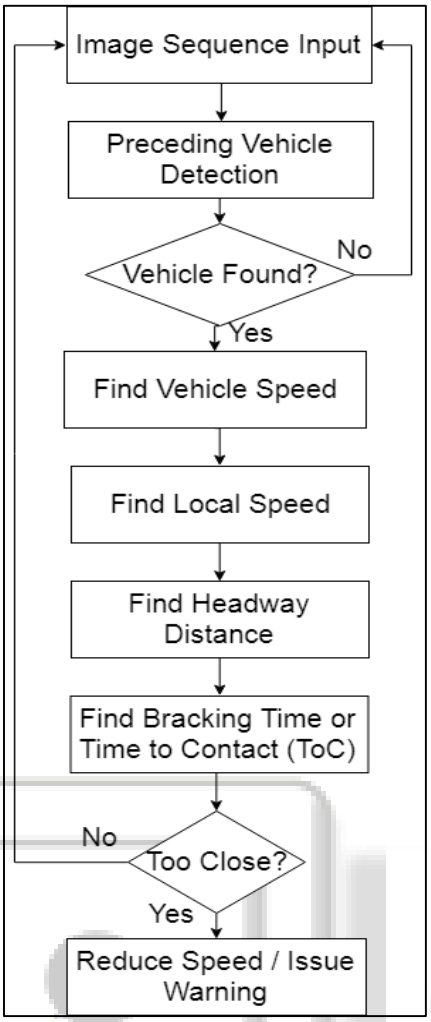

Fig. 1: Adaptive Cruise Control System

C. Europe

Frank et al.(2010) investigated impact of ISA on driver behaviour. The UK ISA system was an overridable system. The ISA control would be resumed when one of the following three conditions was met. 1. The vehicle's speed dropped below the current speed limit. 2. The vehicle reached a new speed zone. 3. The driver voluntarily opted back in. The user behaviour didn't show any behaviour that could be generalised over an exposure of upto 10,000 kms. The system used in the Swedish study is known as an Active Accelerator Pedal (AAP) and is a variant of the ISA system. The system was overridable but could not be completely turned off. In order to exceed the speed limit, the accelerator pedal had to be pressed approximately three to five times harder than would normally be required.

The Swedish data analysis examined the percentage of distance driven with ISA overridden (defined as the vehicle speed being 3 km/h above the speed limit), which denotes the extent to which the effectiveness of the ISA system is compromised.

Stephan et al.(2014) carefully chose a group of Victorian people who held a full current Victorian car licence, and had recently received a three-point Traffic Infringement Notice (TIN) for exceeding the speed limit by 10 km/h or more but less than 25 km/h. Out of a total of eight-six drivers forty were exposed to advised ISA system and other were not. Their driving behaviour was monitored and logged for 12 and 20 weeks for ISA advised group and non ISA advised group respectively. It was observed that ISA advised group had a significantly lower mean speed than the Non ISA advised group. It was also found out from the study that the speed reducing effects of ISA do not remain once the device has been removed from the vehicle. That is, for the eight weeks after the ISA device was removed, speeding behaviour increased and was no longer significantly different from the drivers who had not had an advisory ISA device. Thus ISA system are required in order to get persistent results in this system.

Gámez et al.(2017) proposed a Dynamic Speed Adaptation System was based on analysis of speed limits and curvature information. Using GPS, a database of speed limits based on current path and curvature information and adjusts vehicle speed. Three datasets were used to test this system. A custom dataset,UTBM -2 , UTBM-3 dataset. This system is different from regular ISA system due to the fact that other ISA systems only provide a static speed limit and it doesn't take into account the geometry of the path. The main advantage of their proposed DSA method is its adaptability, since it can be implemented in the vehicle lateral control system independently of the steering wheel angle computation.

United Kingdom: In UK, few remarkable executions of ITS are as follows:

- There is a computerized map for speed limits in the entire city of London for personal, educational or commercial use.
- Intelligent Speed Adaptation has been implemented which displays the allowable speed limit on the dashboard of the vehicle, that constantly reminds the driver not to exceed the limit by mistake. This system is facilitated by the vehicle mounted GPS that detects location of the vehicle and shows the allowable speed limit in the display.
- London Road Safety Unit enforces the speed limit laws by the use of camera, so that people don't break traffic signals.
- Installation of solar powered bus shelters for CCTV supervision and real-time passenger information on display, is under progress to facilitate the bus passengers.
- Conversion of old public transportation buses to hybrid vehicles, to reduce carbon footprint in the country.

III. ITS IN DETAIL

ITS can be divided into following fundamental components [13]:

1) Advanced transportation management systems
2) Advanced traveler information systems
3) Advanced vehicle control systems
4) Business vehicle management
5) Advanced public transportation systems
6) Advanced urban transportation systems

A. Types

1) Vision-based ITS

Vision-based devices are being used broadly in several areas and have generated unparalled quantity of data in recent years due the following reasons.

1) People are more receptive to visual information than any other kind of information
2) Video images can display a lot if information like the status of the system
3) Video sensors are easy to install, operate and maintain.
4) The price-to-performance ratio of a vision-based device has greatly been improved.

2) Multi-source driven ITS

Data driven ITS can also make use of multiple sources like GPS, etc.

3) Learning driven ITS

The use of techniques like machine learning can help implement systems that can adapt to new changes which removes the need to re-code or re-implement these systems.

B. Applications

1) Emergency Vehicle Notification Systems

In-vehicle emergency call can be generated manually or through the activation of the sensors inside the vehicle after the time of the accident.

2) Automatic Road Enforcement

A camera system along with the inbuilt sensors in the vehicle can be used to monitor speed of different vehicles and charge tickets if they disobey the speeding limit.

3) Variable Speed Limits

Road congestions and traffic jams cause drivers to halt after travelling at high speed. This results in wastage of fuel. Hence research is being conducted to have variable speed limits that change as per traffic or congestions to limit the wastage of fuel.

4) Dynamic Traffic Light Sequence

Normal systems use image processing and beam interruption techniques. RFID technology circumvents these problems that adjusts itself even in extreme cases.

5) Collision Avoidance Systems

Countries like Japan have sensors to notify drives if they are likely to collide with other cars.

IV. SUMMARY

ITS or Intelligent Transportation Systems have emerged to to improve safety, mobility and efficiency of transportation. ITS can include ISA or Intelligent Speed Adaptation Systems, Collision Avoidance Systems, Automatic Road Enforcement etc. Research has been conducted in various locations with distinct conditions and technologies to examine the advantages and outcomes. For the past two decades multiple nations, be it developed or developing have started to make investments in these technologies. Studies have been conducted in Africa where Auditory Intervention was used to control driver's speeding behaviours. Countries in Asia, such as Sri Lanka, China, Japan and India have also tested such systems and few of them have such systems functioning already. Middle-Eastern country Dubai has also considered investing in ITS systems due to its ever increasing population count and thus a need a robust system for transportation of civilians. Studies were also conducted in Europe in places such as Sweden, Victoria City (Spain), and UK. There is a computerized map for speed limits in the entire city of London for personal, educational or commercial use. Intelligent Speed Adaptation has been implemented in UK.

A. Problems and Challenges

1) Challenges in Vision-Driven ITS:

Vehicles vary in shape, size, and color. The appearance of a vehicle always changes with its poses change. Complex outdoor environments adds difficulties to the design of vehicle detection and identification system. The computing power is often very demanding due to the rapid movement of on-road vehicles. It is difficult to design a system that is robust to a vehicle's movements and drifts.

Issues with GPS

1) The multipath issue, i.e., a place may receive multiple GPS positioning information, particularly in an urban area with high-rise buildings, where signals from the satellite can be blocked, resulting in potential errors in vehicle positioning data;
2) The missing data issue, e.g., during the time that a vehicle goes through a tunnel.
3) Few visible satellites.

2) Problems occurring with Data-Driven ITS:

Data Cleaning and Preparation: Data is filled with unwanted data which needs to be removed. Noise data occurs due to various known and unknown reasons. It could also occur due to defective sensors.

Dimension Reduction: In ITS the data generally has higher number of dimensions, and as the dimensions increase the "curse of dimensionality" arises i.e., as the number of dimensions increase, the training data needs to increase exponentially. And so to avoid that issue, dimensions are merged and therefore reduced to avoid such issues.

Sparsity Learning: This method removes redundant features from original number of features while maintaining the interpretability of the data. Traffic data consist of several redundant features that need to be removed.

Heterogeneous Learning: Multiple Sensors are used to generate different types of data to improve performance. As a result different types of datasets are generated and are found out to show heterogeneous properties. Thus all the data cannot be directly used to train a model, instead it is required to find a common space, a correlation among the data and use it for training.

3) Cost Issues:

In the vision-driven ITS it is impractical and highly expensive to replace all low-resolution video devices with high-resolution video devices. Enhancing the capability of data analysis by designing an effective and reliable classifier for traffic object recognition can be a possible solution. By identifying alternative devices and developing algorithms for improving their performance the cost issue can be addressed. For example, low-cost DGPS receivers are regarded as a major tool for next-generation automated vehicle location systems. They have a positioning accuracy of approximate 2–3 m.

V. CONCLUSION

From all the papers above we can observe research has been done on theoretical part as well as practically tested in many occurrences. All of the experiments have been fruitful by reducing Accident Rates and having greater benefit for the cost it takes. Drivers have also shown acceptance towards different types of ISA systems. Simulations have been done which extracted curvature information of the roads to provide dynamic speed limits to the drivers. With the rise of smartphones and internet connectivity, one can utilize this opportunity to the fullest and come up with a solution that utilizes the technology to the fullest. ISA have also been proven to save fuel costs and reduce emissions, thus helping the environment. If every vehicle is equipped with ISA there could be a better condition of traffic that we see today. Developed Nations like USA and Canada have systems in place such as Traveller Information Services, Traffic Management Services, Emergency Management Services, Vehicle Safety and Control Systems.

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