Intelligent response to highway traffic situations and road incidents

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Abstract

Intelligent response to traffic situations and road incidents has been employed in Slovenia's highway traffic management system. Human control augmented with an information system enables safer and more efficient highways while drivers are empowered with prompt information on relevant traffic situations. The presented system provides efficient visualization of relevant information, automation of routine tasks and automatic response to critical incidents using expert developed decision models and active collaboration between the operator and the information system. Evaluation has shown a very positive impact of the intelligent highway traffic management system on the traffic safety, as well as being drivers and nature friendly.

1. Introduction

Intelligent response to traffic situations and road incidents has been employed in Slovenia's highway traffic management system. Human control augmented with an information system enables safer and more efficient highways while drivers are empowered with prompt information on relevant traffic situations. The traffic management system currently controls 60 kilometers of Slovenian highways with plans to extend it to all critical segments, i.e. to 200 out of 600 kilometers. The system includes more than 400 cameras, microwave radars, weather stations, height controls, and other sensors, that provide the information system with over 8000 signals about current traffic and weather conditions, including signals about road incidents such as a congestion, wrong way driving and stationary vehicles. Based on the traffic situation and information about road incidents, operators can influence driver behavior using 47 variable message signs or take other corrective actions like notifying police, dispatching road maintenance service or broadcasting a radio message.

The continuous flow of data collected by the large number of sensors requires efficient visualization of relevant information, automation of routine tasks and automatic response to critical incidents. Without efficient visualization the operator could not base his/her decision on immediate traffic situations and incidents but would instead be overwhelmed by the amount of sensor data. Similarly, if routine tasks were not automated the operator's performance would decline due to fatigue and lack of attention. In especially critical incidents, such as wrong way driving (see Fig. 1), the reaction time of operators is inadequate and therefore automatic response is required for initial notification of drivers about the incident.

In the following, we first present how was the intelligent response to traffic situations and road incidents implemented in Slovenia's highway traffic management system and we demonstrate the operation of the system on a particularly critical road incident of wrong way driving. Then we present results of three analyses that show a very positive impact of the intelligent highway traffic management system on the traffic safety. The paper concludes with a discussion of additional benefits of the implemented system.

Figure 1: Surveillance video of the wrong way drive incident. The driver of the small black car has found out that he has missed the exit. Eager to correct his mistake, he has made an u-turn on a platform before tunnel entrance and then he has driven in a wrong way for several kilometers. Please notice the fact (also valid generally), that drivers driving in a wrong way, keep to the right.

2. Slovenia's highway traffic management system

In our implementation of a system providing intelligent response to traffic situations and road incidents, the processing proceeds in three stages (see Fig. 2). In the first stage, the numerical sensor data are categorized and individual signals are combined into states defining the traffic situation. In the second stage, the traffic situation is visualized and presented to the operator (see Fig. 3). In parallel, the information system also continuously monitors and analyzes the traffic situation and signals indicating road incidents using expert-developed decision models. When a potentially dangerous situation or incident is detected, an alarm is triggered either manually by the operator or automatically by the information system. The third stage of intelligent response involves an active collaboration between the operator and the information system. Depending on the type of alarms that are triggered, the information system suggests a list of messages that should be displayed on variable message signs [1]. The operator can modify or completely ignore the suggested list of messages before approving their display. In especially critical incidents, the initial warning messages are displayed automatically within seconds of incident identification.

Most of intelligent behaviour of the information system is encoded in the form of qualitative multi-attribute decision models. In principle, each decision model contains rules that transform some “low-level” data into “high-level” concepts, suggestions or decisions. The system is continuously exposed to an incoming stream of data, such as meteorological measurements (temperature, wind strength and direction, rain, etc.) and traffic data (number and type of vehicles, speed, etc.). In the first stage, this data must be transformed into states and concepts

that describe the specific and potentially dangerous traffic situation, such as: “fog”, “side wind” or “congestion”. In the second stage, traffic states and their history must be transformed into alarms and suggestions to the operator. Due to the number and complexity of these transformations, several tens of decision models are implemented in the system. They have been developed by traffic experts using the method DEX [2] and the software tool DEXi [3].

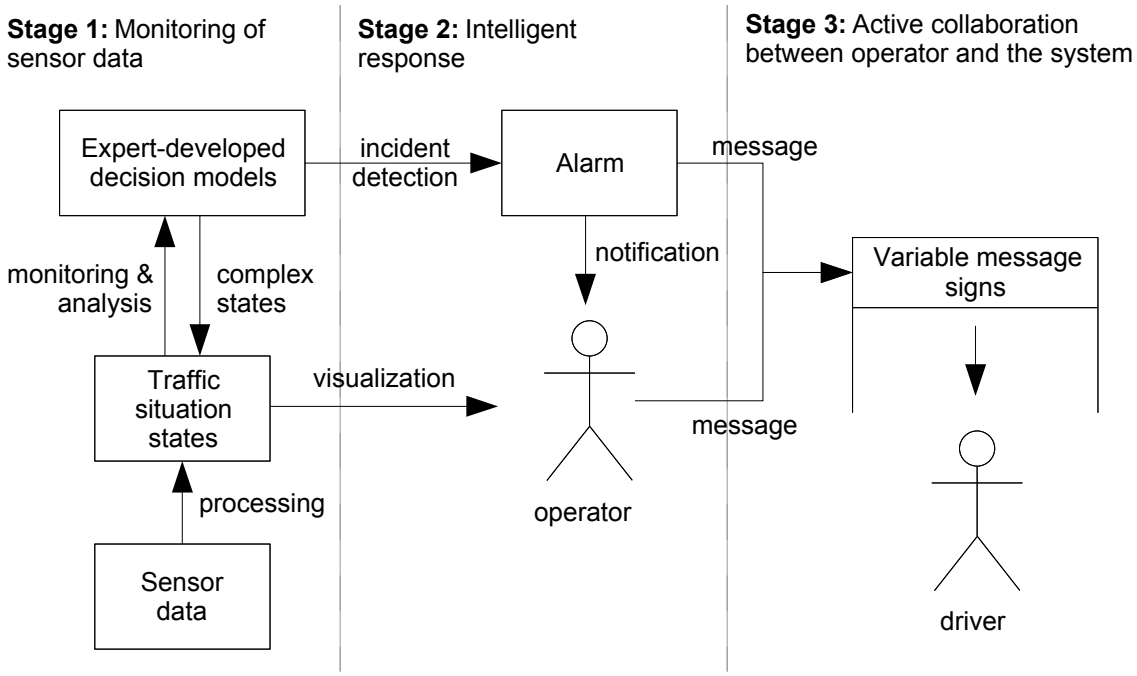

Figure 2: Schematic representation of intelligent response to highway traffic situations and road incidents employed in Slovenia's highway traffic management system.

Figure 3: Control room at the Highway Operations and Maintenance Centre Vransko, Slovenia.

We will demonstrate the stages of the intelligent response of our system to a particularly critical road incident of wrong way driving. Wrong-way crashes are relatively infrequent, but they are more likely to produce serious injuries and fatalities compared to other types of freeway crashes [4]. Our system continuously monitors sensor data. The intelligent response is triggered automatically right after a vehicle that drives the wrong way passes a microwave detector or a

video detection camera. A wrong way drive alarm is immediately triggered resulting in the automatic display of a “harmless” message on the variable message signs which sets the speed limit to 60 km/h, while the operator in the highway operations and maintenance centre is warned about the incident. The third stage of intelligent response requires active collaboration between the operator and the system. The operator must confirm the presence of wrong way driving using video surveillance system, before messages instructing drivers to stop due to the wrong way drive are shown on the variable message signs for the duration of the incident (see Fig. 4).

Figure 4: Variable message sign with a message warning drivers about an ongoing incident of wrong way drive.

3. Impact of intelligent traffic management system on road safety

In the three years since the implementation of the system operators have taken more than 40000 corrective actions concerning immediate traffic situations and incidents. We have evaluated the impact of our system on road safety using three fields studies.

In the first field study, we have analysed the response of the system to highly critical road incident of wrong way driving. The analysis has shown that in these three years 70 occurrences of wrong way driving were detected with 20 of these being false alarms due to specific weather conditions. To the best of our knowledge no occurrence of a wrong way drive went undetected. None of occurrences of wrong way driving resulted in an accident.

In the second field study, we have measured the improvement in response times of maintenance service personnel to various road incidents. The study has shown that the time from the occurrence of the incident and start of corrective actions is much shorter on the highway sections equipped with intelligent traffic management system than on the highway sections without such a system [5]. For example, on the highway section equipped with a system providing intelligent response to traffic situations and road incidents the average response time in the case of a stopped vehicle is almost immediate once the stopped vehicle is detected by the operator, while on sections without such equipment it is estimated to be between thirty minutes and as much as one hour. The response time is that long because maintenance service personnel must first be notified about the incident by highway patrol or drivers themselves, before the dispatch of a maintenance crew that manually conducts corrective actions. Such a slow procedure is rendered useless in case of incidents, such as a wrong way drive or a collision, that demand an immediate response in order to prevent major accidents. In our experiments we have found out that our

system detects wrong way driving in less than a minute, i.e., almost immediately after a car passes the microwave detector or the video detection camera in the wrong direction. We have furthermore observed that drivers have slowed down and moved to the right lane when the warning signs about wrong way driving were displayed, thus substantially alleviating the danger of a head-on crash.

In the third field study, we have analysed the number of the accidents on the highway section between Vransko and Trojane before and after the implementation of the system [5]. The Vransko – Trojane highway section was equipped with the traffic management system in August 2005. Besides the implementation of the traffic management system, no other major changes were done on this road section within the period considered in the analysis.

Year	***2004***	***2005***	***2006***	***2004-2006***
Average Annual Daily Traffic	20.500	22.000	25.000	+22%
Number of accidents	51	34	24	-53%

Table 1: Number of accidents on the highway section between Vransko and Trojane in the years 2004 to 2006.

The results of the analysis given in Table 1 show that the number of the accidents clearly decreased in the year of the system implementation. Although the average annual daily traffic in the year 2006 increased by 22% compared to the year 2004, the number of accidents decreased by 53%. While it is difficult to account for all factors influencing the safety of roads, we strongly believe that the decrease in number of accidents is mainly due to intelligent response to highway traffic situations and rapid response to road incidents enabled by our system. We have observed that the most important corrective action among the corrective actions taken in a collaboration between operator and the system is the display of restrictions and other instructions to drivers on a potentially dangerous road section.

4. Conclusion

In this paper we have presented our implementation of a system providing intelligent response to traffic situations and road incidents. The system continuously visualises, monitors and analyses the traffic situation and signals indicating road incidents, and an intelligent response is triggered immediately after a human operator or an expert-developed decision model detects potentially dangerous situation. Based on the type of a situation, several different corrective actions can be taken, such as notification of drivers using variable message signs, dispatch of the maintenance service personnel, or tunnel closure. Besides providing support for informed decisions by operators performing corrective actions, the high level description of sensor data has provided for better understanding of driver behaviour and highway performance.

We have presented three different studies clearly demonstrating a very positive impact of our system on road safety. Even though the two road sections equipped with our system are considered critical due to particular weather conditions and large number of tunnels and viaducts, the number and severity of accidents that happened on these two sections was relatively low.

The analysis of the impact of the intelligent traffic system presented in this paper has focused on road safety, because the two road sections on which the system is already operating are especially critical from that perspective. The third section of Ljubljana bypass, being equipped with our system right now, is in addition critical also due to high and increasing traffic volumes.

On this section we expect the system not only to provide for better road safety, but also for reduced congestion, higher traffic throughput and road utilisation, resulting also in the reduction of emission of carbon dioxide (CO_2) and other pollutants.

In general the "intelligent highway" equipped with the traffic management system is a safer road, as well as being drivers and nature friendly. Because of the increasing mobility needs of the population, such roads will become an indispensable part of the road network in the near future.

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