Real-Time Fog Warning System for the Abu Dhabi Emirate (UAE)

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Abstract—**Based on historical evidence, driving in heavy fog conditions is one of the most serious causes that lead to massive highway accidents. For example, the Abu Dhabi - Dubai Highway (E10) faced two record accidents in recent times. The first accident was in March 2008 in which more than 200 vehicles were involved in a mass collision. The second was in April 2011 and it involved 130 vehicles. These two massive accidents, and several other relatively minor ones, were due to poor visibility conditions caused by dense fog. Vehicles driving at high speed suddenly enter road sectors covered by dense fog without warning and are then implicated in mass collisions. The main objective of this research is to improve road safety in Abu Dhabi when drivers face poor visibility conditions caused by dense fog. This is achieved by sending early real-time warning signals to all drivers who are about to enter poor visibility sections of the highway of the dangers ahead, using radio signals or cell phone voice-based short messages. Warning signals can also be displayed to the drivers using Changeable Message Signs (CMS) installed along the highway. The concept and architecture of a novel, modular fog warning system are presented.**

Index Terms—**Fog warning system, traffic control, geographic information system (GIS), mobile devices, smart phones, weather condition reporting system, poor visibility, intelligent transportation systems (ITS), fog sensor, Changeable Message Sign (CMS).**

I. Introduction

Accidents arising from a combination of poor visibility due to fog and high vehicle speeds result in significant economic cost due to the loss of life and injury as well as damage to vehicles [1]-[4]. Furthermore, delay to motorists as a consequence of these incidents further adds to economic cost. Based on historical evidence, Abu Dhabi Emirate has suffered from such incidents. In this research study, we propose the implementation of a early real-time fog warning system which can help to alleviate these issues. This system would be a multipurpose: it will detect the presence of fog, warn in real-time motorists of the presence of fog, instructing them to reduce speed, advise them about the level of speed, and may be provide advance diversionary routing information to allow motorists to avoid affected areas and also provide the authorities with an early real-time warning of fog hazard.

A. Other Fog Detection and Warning Systems

The fog detection and warning systems have been around the world long time ago. In this section, we present some of these systems which have been found in the literature review.

Fog-detection and warning system, Georgia: The system has been implemented in 2001 and is located along 12 miles stretch of I-75, near Adel. It consists of 19 fog sensors, 10 sets of traffic monitoring loops, weather instruments, 5 closed-circuit televisions, and 4 CMS on the north- and southbound outskirts of the fog zone. In fog conditions, the central computer automatically notifies officials at the Transportation Management Center in Atlanta, send cautionary messages to the CMS, and turns on streetlights on the roadway [4].

The fog-detection and warning system, Tennessee: The system has been implemented in 1994, prompted by a 99-vehicle pileup in December 1990. It has been located along 19 miles of the I-75, near the Hiwassee River. In that system, a central computer receives data from 8 fog and 44 speed detectors. Based upon the received data, the center managers with Tennessee Department Of Transportation (DOT) and Tennessee Highway Patrol select pre-programmed CMS messages, pre-recorded Highway Advisory Radio (HAR) messages, and appropriate speed limits (35 or 50 mph). Then motorists are advised of fog conditions using 6 static signs, 2 HAR transmitters, 10 CMS, 10 Variable Speed Limit (VSL) signs, and automatic ramp gates. Under worst-case (visibility less than 240 feet), the Highway Patrol activated the ramp gates and detour traffic to US Route 11. As results, it has been shown that there is no fog-related accidents reported after installing the system, while from 1973 to 1994, there were over 200 crashed, 130 injuries, and 18 fatalities on the section [4].

Fog-detection and warning project, Netherlands: This system is located along 7.5 miles of the A16, near Breda and has been activated on 1991. It uses 20 visibility sensors as input and variable message signs every 0.4 to

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0.5 miles. The variable speed limits proposed by the system depend upon the visibility. The system presents flexible speed limits and warning displays that can be varied to match traffic and environmental conditions, including fog. After using this system, it has been shown that the mean speeds at all of the monitoring stations were reduced by 8 to 10 km/h during fog conditions, but the mean speed still above displayed speeds. The researchers concluded that the system has positive effects on driver behavior during fog because 50% reduction in secondary accidents has been reported [4].

Variable speed limits on Autobahn, Germany: This system has been in use since 1960 on sections of the autobahn in urban areas in order to improve traffic flow and adapt traffic to adverse environmental conditions. Due to high costs, the system has been installed on a priority basis on hazardous sections, especially in areas of adverse environmental conditions. In this system, the vehicles speed and count have been monitored through inductive loops by using fog, ice, wind and other environment conditions detectors. Then, computer algorithms actuate CMSs for the conditions detected. Displays can also be operated manually. In addition to the speed limit, the reason for the restriction is also displayed. After using such system, it has been shown that the accident rate has been reduced by 20 to 30 percent, with an average reduction of 25 percent [4] [5] [15].

Fog warning and advisory speed limit system, Australia: This system has been installed in 1993 along an 11-km section of the F6 Tollway south of Sydney. It uses 12 fiber-optic sign locations, with signs in both directions, ~1 km apart. Each location is equipped with inductive loops and a visibility detector. This system is fully automated, so the speed of each vehicle is measured over a distance of 200m, and this speed is used to present an advisory speed to the next vehicle passing the station. The advisory speed is based on visibility distance and the speed of the preceding vehicle. As results, it has been shown the reduction of 60 percent of the vehicles traveling in excess of the speed limit. Effect is temporary, because 300 m downstream, there is no reduction in speeds [4] [14].

M25 automatic fog warning system, London, England: This system has been implemented in 1990 on M25 London Orbital Motorway. It has six visibility detection sites. When visibility drops below a minimum threshold, remotely activated fixed warning signals are automatically activated. After using such system, the Transportation Research Laboratory has observed an overall reduction in mean speeds of about 1.8 mph when signals were activated [4] [6].

The weather-controlled road system, Finland: This system has been implemented in 1994. It is located along a 15.5 mile section of E18 between Pyhtaa and Hamina. It consists of 5 automatic road weather monitoring stations, 66 VSLs signs, and 13 CMSs. The sensors at each station measure wind speed and direction, air temperature, roadway surface temperature, humidity, intensity and state of precipitation, visibility, and road surface (wet, dry, icy). As results, the system succeeded in reducing mean speeds and variance in adverse conditions, 95% of drivers interviewed said that varying speed limits were useful and enhance traffic safety [4] [7] [10].

Variable speed limit project- Nevada: The system uses 22 weather stations installed throughout the state. The sensors monitor air temperature, wind speed and direction, humidity, precipitation, dew point, visibility, road condition (wet, dry, icy), pavement surface and subsurface temperature, and the amount of chemical on the roadway. Vehicle speeds are also monitored along I-80, 15 miles east of Reno. This data is used to calculate the appropriate speed for current weather conditions. The speed will be shown on the VSL signs. If speed limits are reduced, signs will be activated that read “Reduce speed when flashing” [4] [11].

TravelAid, Washington State: The system has been implemented in the winter of 1997/1998. It is located along the I-90, across Snoqualmie Pass. In the system, we have 13 CMS that display enforceable speed limits and/or messages. Decision to reduce speeds is based upon vehicle speeds, volume, and classification, atmospheric conditions, and observations from Washington State Department Of Transportation (DOT) maintenance personnel and the State Patrol. The system is manually controlled, but it goals in the future is to automatically post safe speeds based upon real-time data [4].

Strom warning system, Idaho: That system has been implemented in 1993 in response to 18 major visibility-related crashes between 1988 and 1993, involving a total of 91 vehicles. It is located along the I-84 in southeast Idaho. It consists of sensors to measure traffic, visibility, roadway, and weather data, video cameras to verify visibility readings, and 4 CMS. Idaho transportation department receives alerts from the central computer and decides which message to display on the CMS [4] [9] [12].

Adverse Visibility Information System (ADVISE), Utah: The system has been implemented in the winter of 1999/2000. It is located on I-215 southbound, between Redwood Rd. and the I-215/I-15 interchange in Salt Lake City. It consists of 4 visibility sensors, 2 CMS, and 6 traffic counters. In the system, a central computer identifies threats using visibility, vehicle speed, and vehicle classification, and prompts display of an adaptive speed limit and warning message [4] [8] [13].

B. Summary about Other Fog Detection and Warning Systems

Even most of the presented systems have shown their efficiency, they have some limitations which are presented as follow:

Most of the systems use static instrument such as fog sensors which affects the cost of the system or limits the covered zone.

The notification system use static instruments such as CMS which are installed in pre-defined places in order to notify the drivers. Even if the driver is notified, he/she does not know the exact boundary of the poor visibility area.

These systems just notify the drivers about the foggy zone but they don't propose any other alternative for them.

II. Our Proposed Real-time Fog Warning System

A. Our Proposed System

Abu Dhabi - Dubai Highway (E10) faced two record accidents in recent times. The first accident was in March 2008 in which more than 200 vehicles were involved in a mass collision. The second was in April 2011 and it involved 130 vehicles. These two massive accidents, and several other relatively minor ones, were due to poor visibility conditions caused by dense fog. These tragic events prompt us to think about an efficient solution which consists of an early and real-time fog detection and warning system. The architecture of the system is presented in Fig. 1.

B. The Architecture of the System

The proposed fog warning system consists of three components:

Fog sensing (detection) component,

Fog density data collection and analysis component, and

Driver fog notification (signaling) component.

The architecture of the system is presented in Fig. 1.

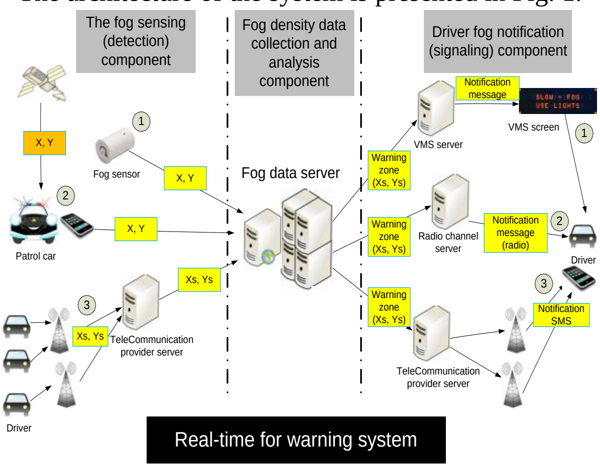

Figure 1. The architecture of the Real-Time Fog Warning System.

The components of the systems are detailed as follow:

1) The fog sensing (detection component): This component has the main function of detecting the formation of fog and determining the geographical locations of the boundaries of foggy zones. There are several methods for determining the conditions and locations of poor visibility sectors of the highways and these include:

Fog sensors: Installation of fog sensors on light poles, radar stations or cell phone towers along the highway. Data from the sensors is collected by an appropriate communications network and fed to the fog data collection and analysis component,

Real-time incident detection tools/applications: Detection of slow traffic movement due to poor visibility conditions by the cell phone networks which tracks the movement of wireless devices inside vehicles driving along the highway. Such information is then passed on to the fog data collection and analysis system.

Police cars on patrol: in this case, the patrol officer would approach the boundary of the fog-afflicted zone and send a signal to the data collection component while at the boundary point. This is done by simply pushing a single screen icon on a smart phone set which is programmed to send a data through the 3G data network. This data contains the coordinates of the boundary of the foggy zone to the fog data collection and analysis component (second component of the system). This technique is very efficient because it is dynamic (not restricted by the location of the sensors) and can cover any zone in Abu Dhabi area. In the first prototype of our system, this option will be implemented (see Fig. 2).

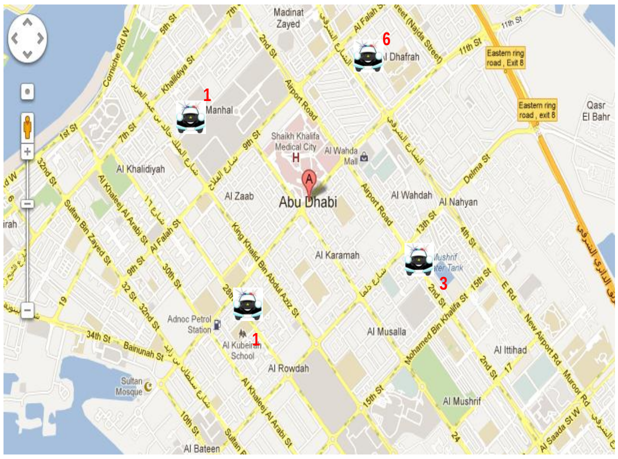

Figure 2. Four cars signaling the boundaries of a foggy zone

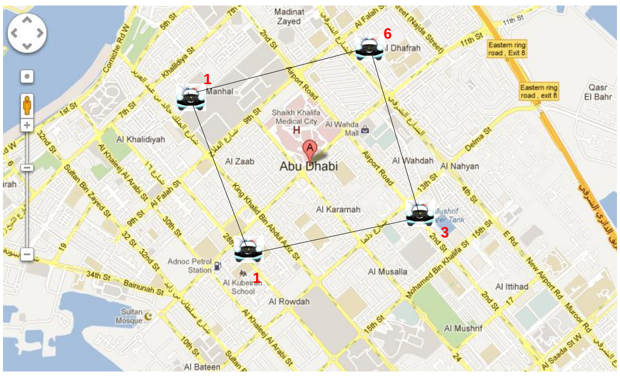

Figure 3. The construction of boundaries of the virtual foggy zone on the GeoDatabase of Abu Dhabi

2) The fog density data collection and analysis component: This component is a computational server programmed to collect real-time data from one or more of the sources of information of the fog sensing components and to conduct the appropriate analysis to determine, on the GIS of the Abu Dhabi area, with reasonable degree of accuracy the geographical boundaries of the poor visibility sectors of the highway caused by fog formation (see Fig. 3). It is important to mention that the accuracy of the virtual foggy zone depends on the number of patrol cars detecting the fog. This system, save the detected foggy zones in its database for further analysis in order to define which area of Abu Dhabi is affected frequently by fog so the decision makers can take further actions and precautions concerning this issue.

3) Driver fog notification (signaling) component: Once the boundaries of the fog-affected zone(s) are determined, they will be sent to the server of the telecommunication operator, and this later will transmit warning signals to all drivers approaching the poor visibility sectors and well before they reach such location in order to take appropriate precautions. This is essentially the function of the driver notification (signaling) component.

In our system, there are three possible methods for driver notification:

Notification option 1: In this option the server sends a notification messages to all the CMSs around or inside the foggy zone. The concerned CMSs will be defined by using the GIS of Abu Dhabi Area. This is the simplest and most straightforward approach. In practice, this approach has two shortcomings: the first is that the drivers may miss reading the sign at the appropriate time, and the second is the inadequate warning distance if the sign is too close or too far from the boundary of the foggy zone,

Notification option 2: Activating a channel on the vehicle radio that would automatically warn the drivers of the danger ahead. This will require that all vehicles are equipped with dedicated radio weather channels that are remotely activated, which is not true in practice. Furthermore, the warning signal is neither user selective, nor location selective. That is, all drivers will receive the warning signal,

Notification option 3: The transmission of SMS (data or voice) to the drivers' cell phone devices with the fog warning signal. In this case, the cell phone device will be pre-programmed to display the signal once received from the driver notification component. Only drivers approaching the boundaries of the poor visibility zone will receive such warning messages. The key issue here is that in order to receive such warning signal in time, the driver must have the cell phone switched on all the time and it must be possible to program the device so that its GIS location is tracked and it is able to identify and interpret the warning signal. Most modern cell phones have these capabilities. For subscribed users the system can propose to them the alternative way to reach their destination, if it has been already mentioned by the drivers. In the first prototype of the system, only this option will be implemented.

III. ORIGINALITY, CONCLUSION AND FUTURE WORK

The proposed system is intended to overcome the major drawbacks of fog warning systems which have been developed previously. In existing systems, fog detection is accomplished using sensors or similar devices which have specific fixed positions, while in the proposed system we benefit from the mobile and smart phone technologies in order to detect the fog dynamically in any location of the coverage area. Moreover, the detected information about fog conditions can be analyzed using advanced techniques which are based on location and artificial intelligence. By using such advanced analysis techniques we define efficiently and accurately the boundaries of the fog zones in the coverage area under consideration. Concerning the notification component, the previous systems use fixed notification devices such as CMS where the locations are fixed, while in the proposed system we use a dynamic mobile and early notification technique whereby the users are warned ahead of time and before they approach the fog zone. Using advanced technologies such GIS and mobile technologies makes our system more efficient than existing systems. In terms of the architecture, our system can be distinguished from the previous systems because its components can be specified, designed and implemented independently. The system is thus based on a flexible, modular structure. Such a flexible structure will make it possible in the future to enhance each component without having to redesign the other components. Examples of such enhancements include incorporating new sensor technologies in future into the first component, adding more analytical capability to the second component, and adding more channels or media to the driver fog notification component to enhance reliability and improve user access. Moreover, this system can be easily configured in order to provide early warning on other weather conditions such as storms, heavy rains, etc.

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