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DYNAMIC INCIDENT REPORTING AND WARNING SYSTEM FOR SAFE DRIVE

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Abstract. *This paper proposes the development of an incident reporting and warning system helpful for mitigating road traffic risks. To avoid road accident, there is a need to have information for precaution while driving along a route. A mobile phone is a device that a driver carries with oneself. There exist some mobile applications informing a driver about incidents up ahead. However, mobile phone use grows the problem of distracting a driver. A report from the Thai Health Promotion Foundation in 2013 stated that mobile phone use caused 729,997 accidents and almost caused 1,152,999 accidents. The foundation also suggested using auxiliaries helping a driver to use a mobile phone without touching and looking at it. The suggestion leads to the main contribution of this work to develop a mobile application that can inform a driver about traffic signs and accidents up ahead by using a text-to-speech service. Moreover, this work considers lost from the delayed response from rescue services. The application also has a function for a driver to report an accident. The information is then dispatched to nearby rescue services, and the application will then navigate a rescue service to the scene of the accident. This process helps a rescue to respond to a critical accident requiring first aid quickly. To achieve these, this work proposes not only a mobile application but also a system supporting the requirements. The architecture of the system, the use cases, and a prototype of the mobile application are presented.*
Keywords: Accident reporting, Accident alarm, Accident warning, Traffic sign warning, Mobile application, Text-to-speech

1. **Introduction.** From a recent report of the World Health Organization, road traffic injuries are the 8th leading cause of death, and they are also the 1st leading cause of death among children and young adults aged 5-29. Every year approximately 1.35 million lives are lost as a result of a road traffic crash. 20-50 million more people suffer from non-deadly injuries. Many of them encounter disabilities from their injuries. Road traffic injuries not only cause losses to individuals but also their families and to their countries. These losses are from productivity decreased from those who are killed or disabled by their injuries, from the cost of their treatments, and from time off from work of their family members who have to take care of them as well. Statistics show that road traffic injuries cost 3% of the gross domestic product in most countries [1].

There are many risk factors in road traffic accidents. The important factors for this work are speeding, unsafe road infrastructure, inadequate post-crash care, and distracted driving. For speeding, an increase in average speed influences the possibility of a crash

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occurring and also impacts the severity of the injuries from the crash. For unsafe road infrastructure, roads should be designed for the safety of all road users, including pedestrians who need safe crossing points. Inadequate post-crash care is related to delays in detecting, reporting, and providing first aid for those involved in a road traffic accident. Care of injuries after an accident is a time-sensitive task, i.e., delays of minutes can increase the severity of injuries. Distracted driving is a growing concern for road safety since more and more people own mobile phones. Use of a mobile phone while driving increases reaction times and puts a driver into four times riskier situation than drivers who are not using a mobile phone.

Traffic signs informing speed limits, pedestrian crossing, etc. have been already used to mitigate problems from speeding and unsafe road infrastructure. However, disobeying or ignoring traffic signs may reduce the effectiveness of notification. These sometimes are from clearness and interpretability of traffic signs. This leads to the main contribution of this work. We propose the development of a dynamic warning system notifying a driver about the information of traffic signs before the driver will reach the signs by using a mobile application instead of looking at and interpreting traffic signs by a driver. Moreover, the application informs a driver with both text and voice notifications to avoid the distracted driving problem while this feature does not exist in the previous systems.

The proposed system supports not only traffic sign warning but also accident up ahead warning. The application offers a function for a driver to report an accident. The information of a reported accident will be recorded into the database server and sent to moderators. The information will be then verified by a moderator. If the accident exists, the information will be distributed to applications running on mobile phones for the warning purpose. Moreover, if the accident requires first aid care, the information will be dispatched to rescue services nearby the scene of the accident. This is helpful for relieving the inadequate post-crash care problem. The participation of rescue services in the system is another contribution not appearing in the existing systems.

The organization of this paper is as follows. Existing systems and feature comparison are described in Section 2. The architecture and the use cases of the proposed system are explained in Section 3. The development of the mobile application is presented in Section 4. The conclusion and improvements of this work are discussed in Section 5.

2. **Related Work.**

2.1. **Previous systems.** In this section, some traffic warning systems are investigated. The conventional accident notification systems were built in a car, for example, Automatic Crash Notification System of BMW or OnStar of GM. They detect car accidents with built-in sensors which are accelerometer and airbag deployment monitors. When an accident is detected, the system immediately sends a notification to emergency responders by using a built-in cellular radio. Unfortunately, such a sophisticated system requires a cellular radio communication infrastructure and is not included in most cars. However, the research in [2] stated that automatic traffic accident detection and notification systems could have saved 2,460 victims based on 2007 traffic accident data. This presented a good start for traffic warning systems.

Nowadays, the mobile phone has become a personal device for an individual. It is a promising alternative for road accident detection, reporting, and warning tasks. There exist many pieces of research focusing on automatic road accident detections. The recent survey researches related to automatic road accident detections by using a mobile phone are presented in [3, 4], but they are out of the scope of this work. The main purpose of this work is to utilize a mobile phone for the accident reporting and the accident warning for a driver. These functions seem to be trivial, but the existing systems still lack some necessary features.

The Android application called *HDy Copilot* in [5] was developed to work with an ODB-II device equipped on a vehicle. The data collected from built-in sensors of the mobile phone, the accelerometer, the gyroscope, and the magnetometer are combined with the airbag data obtained from the ODB-II device for automatically detecting a road accident. Once an accident has been detected, road hazard warnings are transmitted to nearby vehicles via the IT2S platform. The information regarding the accident is then sent to a specific emergency service via an email and a Short Message Service. After that, the mobile phone will make a call to the emergency service. The main shortcoming of this system is the use of the specific IT2S platform for vehicle communications.

Beat the Traffic [6] was previously available for both iPhone and Android phones, but it is no longer available since January 2017. It provided real-time traffic information and maps for most major cities in the US and Canada. The accident reporting function was also offered. The function came with the *shake to report* feature which allowed a user to report an accident by simply shaking the mobile phone.

AxiKit App [7] provides a customizable accident report system for an organization. It guides a driver step-by-step at the scene of an accident to capture important information related to the accident. It organizes voice recordings, photographs, and all crucial data into a report which can be easily transmitted by an email. The application also has an emergency button for a driver to call a predefined contact. It is suitable for an organization to track incidents of its vehicles but not for community services.

INRIX Traffic [8] is another mobile application currently available for both iOS and Android operating systems. Its key features are the ability to report incidents, incident reports informing a driver of construction, accidents, hazards, events, lane closures, and closed roads and safety alerts to protect a driver from sudden slowdowns and road conditions up ahead. This application also provides useful features for traffic routing. It is closely related to our proposed system regarding the incident reporting. However, coordination with emergency services is not included in the system.

2.2. **Feature comparison.** In the Introduction, the risk factors concerned in this work are speeding, unsafe road infrastructure, inadequate post-crash care, and distracted driving. To utilize a mobile phone for decreasing risks from these factors, we conclude with eight necessary features which should be in a mobile application, and they will be used to compare with the existing systems.

The first three features are in regard to incident reporting and information updating procedures. A common ability to report an accident occurring to a driver is the first feature (f1). The second feature (f2) is a function to report any incident not occurring to a driver. This is the main feature that is used by a driving user who spots an incident not only an accident but also a missing traffic sign, a pedestrian crossing, or a road condition. The third feature (f3) is the use of a GPS location service to localize a driver and an incident automatically. It is helpful for warning a driver to slow down a vehicle when an incident is near and for decreasing delays of an accident reporting.

The remaining features are about information displays and real-time warning abilities. The fourth feature (f4) is the use of a map service for displaying traffic information. This feature is useful for a driver to prepare himself for what he will confront along a path. Moreover, it can be used for a driver to decide to take a detour for traffic avoidance. The fifth feature (f5) is a display of incident pins along a route on the map to synergize with the f4 feature. Another necessary feature for a driver is a notification of an up-ahead incident (f6). It is crucial for suppressing speeding and unsafe road infrastructure risk factors. However, if the notification is in a text form, it will cause a distracted driving problem. Therefore, we propose the seventh feature (f7), the use of a text-to-speech service allowing the application to notify a user about the information of an incident by using voice. To give priority to the inadequate post-crash care problem, rescue services are needed to participate in the system. The eighth feature (f8) for accident information dispatching to nearby rescue services is included in our consideration. The feature also comes with a navigation system finding the fastest route to the scene of an accident.

As we have discussed above, Table 1 summarizes the feature comparison among our proposed system and the existing systems. The f7 and f8 features are added into our system to provide more safety for drivers and victims.

TABLE 1. Feature comparison

Application	f1	f2	f3	f4	f5	f6	f7	f8
HDy Copilot	√					√		
Beat the Traffic	√	√	√	√	√			
AxiKit App	√							
INRIX Traffic	√	√	√	√	√	√		
Dynamic Warning Message for Safe Drive	√	√	√	√	√	√	√	√

3. Proposed System.

3.1. The architecture. The main purpose of our system is to inform important traffic signs and accidents to a user who is running the application while driving a car. Only incidents that the user will confront in the near future are informed via the application. To achieve this, the application requires traffic sign information and accident information along a route and the current GPS position from the mobile phone running the application. The traffic sign information and the accident information are different in the aspect of volatility. The former is mostly invariant, whereas the latter frequently changes. Therefore, we design a system consisting of four main parts, a database server, a road survey, an information updating procedure, and a real-time warning. Figure 1 presents

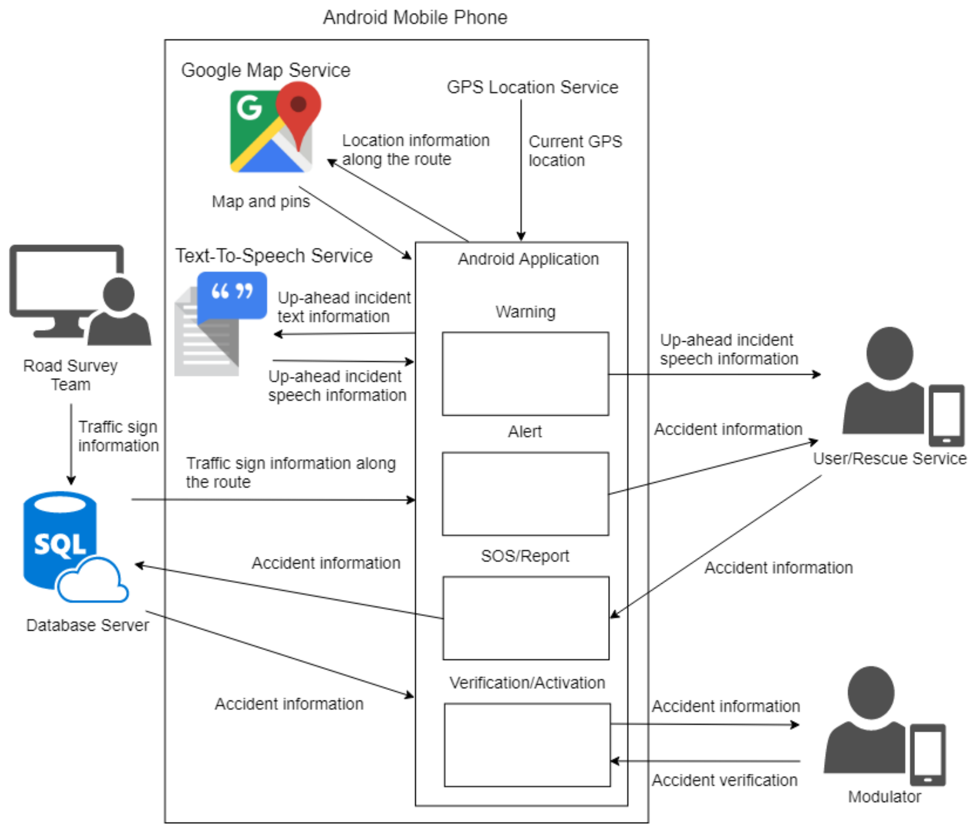

FIGURE 1. The architecture of the proposed system

the architecture of the proposed system, including all the features and all the information distributed through the system. The details of the main parts will be explained as follows.

3.1.1. *The database server.* In this work, a centralized database server is used to store traffic data. It is deployed where it can be accessed from anywhere via the Internet. The necessary information can be stored in one table with the fields, event ID, event name, timestamp, latitude, longitude, direction, type of incident, level of importance, rescue/non-rescue, volatility, active/inactive, and base64 images. Most fields are straightforward except the direction, type of incident, level of importance, rescue/non-rescue, and volatility fields. The direction field indicates that an incident occurs on an inbound or outbound direction. The type of incident field is chosen from a category of all incidents that can appear on roads. To emphasize a critical incident, the level of importance field provides information to rate a traffic sign or an accident. The rescue/non-rescue field indicates a need for the rescue of an incident. The volatility field is used to decide if an incident will appear on the map and warned to a user. It stores a time interval in which an incident is triggered inactive when its time interval has passed.

3.1.2. *The road survey.* A road survey is performed once to collect important traffic signs along a route. Traffic sign data is extracted from video files recorded by using Garmin GDR E560, a GPS-enabled dashboard camera. Figure 2 shows examples of two traffic signs. A green rectangle represents traffic signs while a yellow rectangle and a red rectangle on the bottom of the figure represent a location in the latitude and longitude coordinates. The sign in Figure 2(a) is a steep hill ascent warning sign. The sign in Figure 2(b) contains a sharp double curve, first to left warning sign with a speed limit sign. For the latter case, there are two traffic sign data sharing the same location, which will be stored in the database. Once the traffic sign data has been obtained, it is then stored in the database with the *nonvolatile* and the *active* properties. All the data records collected along a route share the same inbound/outbound direction.

(a) (b)

FIGURE 2. Examples of some traffic signs appearing along a route

3.1.3. *The information updating procedure.* The information updating procedure is a module in the mobile application. Additional incidents, for example, road constructions, potholes, and accidents, can be added by this module. An incident can be reported by any user, but it will be verified by a moderator. If the incident is valid, it will be stored in the database with the *active* property. The volatility field is appropriately defined by the moderator. Moreover, if a rescue is needed for the incident, the rescue/non-rescue field is set to *rescue* or otherwise. In the case of a rescue incident, when the rescue has been achieved, the status of the incident is triggered to *inactive* by the rescue service. The application also provides another way to report an emergent accident, SOS button. By pressing the SOS button, a user is not needed to fill in any information. The default field values are assigned, especially with the *rescue* property. This feature is very useful in two situations, when an accident happens to a user or when a user is driving and spots an accident. Updated information is distributed to users by using the polling technique in every five seconds. The stored information and the Google Maps module in the application will be updated when new information has been retrieved.

3.1.4. *The real-time warning.* The real-time warning is also a part of the application, but the function for a rescue service is different from that for a driver. A recently approved incident that needs rescue is immediately alerted to the applications for nearby rescue services whereas the incident dynamically appears in maps and will be warned when a driver is heading to the incident, and the distance between a driver and the incident is less than one kilometer. To use the warning function for a driver, a driver has to identify a route and an inbound/outbound direction to avoid false alarm from the opposite direction. The route and incidents along the route will be visualized in Google Maps. An incident is represented by a pin which is located by using the latitude and the longitude coordinates and labeled by its *event name*. An advantage of our warning system is from the use of Google text-to-speech, which acquires the event name and the type of an incident as an input, and then pronounce the information to a user. This is helpful for a user to avoid risk from looking at the mobile phone while driving.

3.2. **The use cases.** The use cases explained in this work are for the mobile application only. The list of actors consists of drivers, moderators, and rescue services. There are five use cases for the application: regular incident reporting, emergent accident reporting, incident verification, alarm for rescue services, and warning message for a driver. The details of the use cases are explained as follows.

Use Case #1:	Regular incident reporting
Actor:	Driver
Scenario:	1) A driver spots an incident or has an accident. 2) The driver launches the application. 3) The driver accesses to the incident reporting activity. 4) The driver takes some images of the incident. 5) The driver fills in the incident information. 6) The driver sends the report.
Use Case #2:	Emergent accident reporting
Actor:	Driver
Scenario:	1) A driver spots an emergent accident or has an accident. 2) The driver launches the application. 3) The driver presses the SOS button. 4) The report is sent with the default information.
Use Case #3:	Incident verification
Actor:	Moderator
Scenario:	1) A report is received from a driver. 2) The application alerts moderators and displays the information. 3) A moderator verifies the incident. 4) The moderator edits some missing information. 5) The moderator presses approve button or reject button.
Use Case #4:	Alarm for rescue services
Actor:	Rescue service
Scenario:	1) The application alerts rescue services and displays the information. 2) A rescue service accepts the case. 3) The application navigates to the scene of the accident.

Use Case #5:	Warning message for a driver
Actor:	Driver
Scenario:	1) A driver launches the application. 2) The driver searches for a destination. 3) The driver chooses a route. 4) The incidents along the route are displayed. 5) The driver starts the navigation. 6) The application alerts every single incident within one kilometer to the driver by using Google text-to-speech.

4. **The Mobile Application.** Some important activities in the mobile application are shown in Figure 3. A driver selects a route from the first activity in Figure 3(a). In this prototype, we focus on three popular routes from Phitsanulok province to Phetchabun province, which are the most accident occurring routes in the lower northern area of Thailand. The activity displays the desired route and occurring incidents. Figure 3(b) exemplifies a notification of a traffic sign. The notification also informs a driver with

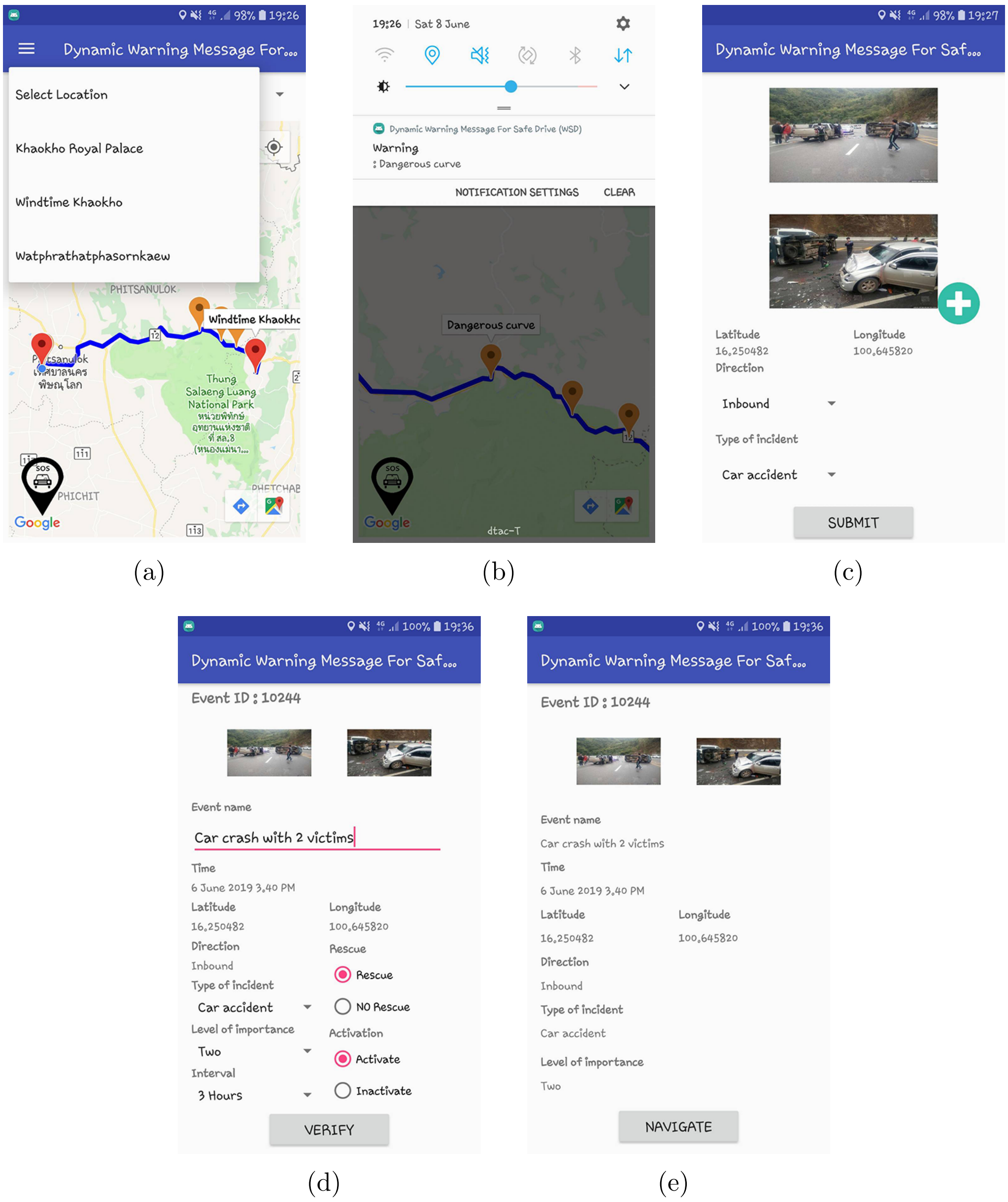

Figure 3. Mobile application activities

Google text-to-speech. A user can report an accident by using the activity in Figure 3(c), which allows a user to take images of the accident for verification. The information is verified, and additional necessary information can be filled in by a moderator, as shown in Figure 3(d). Once the accident has been approved, the associated information is then dispatched to nearby rescue services with the activity in Figure 3(e) which is an additional activity helpful for mitigating risks from inadequate post-crash care.

5. **Conclusions and Future Work.** This work considers a system for incident warnings to drivers. The system is mainly operated on mobile phones as the terminals for contributors, drivers, moderators and rescue services. The purposes of using the system are to decrease four risk factors, speeding, unsafe road infrastructure, inadequate post-crash care, and distracted driving. The first two factors can be mitigated by using the main application to warn a driver about traffic signs, speed limits, or accidents up ahead. Incident reporting is also offered in the application. A driver can report additional traffic signs, road conditions, and accidents. A reported incident will be verified by a moderator. An approved incident will be then broadcast to drivers who are on the corresponding route of the incident. Rescue services are welcomed to participate in the system to be in charge of post-crash cares. The application provides information about an accident and navigates a rescue service to the scene of the accident. To avoid the distracted driving factor, the warning feature applies a text-to-speech service to notifying a driver by using voice instead of looking at a mobile phone. Based on these requirements, the architecture of the system and a prototype of an Android application have been proposed.

However, the proposed system still lacks automatic features for driving style analysis and crash detection. For example, the speed of a vehicle can be calculated by collecting and analyzing GPS data of a mobile phone over a distance [9]. By using accelerometers of a mobile phone, vehicle moving direction, and driving style can be estimated by applying deep neural networks [10]. These analyses can be combined for anomaly driving behavior detection. For automatic crash detection, GPS, accelerometers, and a microphone can be used to detect an accident occurring to a driver [2, 11]. These features and the finalized application will be included in our future work.

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