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Routing and Navigation Solutions for Emergency Vehicles in Urban Emergency Management

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Abstract

Urban population and expansion continue to rise, as have emergencies, and emergency response times are becoming longer in the city. Response times are critical in urban emergency management. Traditional navigation systems do not consider the preferential road usage rights and requirements crucial for emergency teams such as ambulances, fire departments, and police. In traditional navigation systems, features such as safety lanes and road width are not incorporated as routing criteria. Past emergency navigation studies do not contain many variables and this causes delays in emergency response processes. As a result, applications that process real-time traffic information and provide guidance according to different vehicle types are needed for emergency management.. This study aims to develop an application capable of routing for different vehicles according to criteria such as working hours, holidays, weather conditions, and seasonal effects. The application is developed with a novel approach in this context using machine learning methods and produces alternate routes with GPS navigation based on the real-time traffic situation. Moreover, the software also provides routing solutions for trucks, freight distribution, and automobiles and recommends unique routes for emergency vehicles based on factors including safety lanes, road width, corner turning angles, and right of way. The expected outcomes upon implementing this application include easy and fast access to the emergency locations, reduced response times, and improvement in urban emergency management services.

Keywords

Emergency management; Navigation, Routing; Machine learning.

1. Introduction

Managing the risk of disasters is one of the crucial goals due to the increasing population, human settlements, and climate change for 2030 (United Nations, 2022). Emergency management is necessary to effectively deal with urban challenges and is also important for achieving the 2030 Sustainable Development Goals (SDG) (Cao et al., 2018). Previous studies advocated sustainable development and adaptation to climate change in disaster risk reduction and mentioned that emergency management plays a key role in this context (Murray et al., 2017; O'Brien et al., 2006; Saunders et al., 2020). On the other hand, emergency management emerges as a goal not only for sustainable cities but also for smart cities with the widespread use of the Internet of Things (IoT) and Global Positioning System (GPS) (Sumi and Ranga, 2018).

The quick arrival of emergency vehicles (ambulances, fire trucks, etc.) on the scene is crucial to protect human life and safety (Sarı, 2017). Especially ambulance vehicles are essential to solving vital problems such as accident trauma or heart attack (Myers et al., 2008). In this context, the health centre's response time to emergency vehicle signals must be reduced to decrease the death risk (H. Blackwell and S. Kaufman, 2002; Langabeer et al., 2016). Regarding natural disasters, emergency management again has a crucial role as it targets to fight the damaging effects of natural disasters and reduce the health risks associated with future disasters (Wright et al., 2020). From this point, many emergency management/emergency vehicle studies exist in the literature. A good number of researches, such as IoT-supported traffic signaling and automatic road speed reduction in particular areas, including school districts, were conducted (Ahir et. al., 2018; Amudhavalli et al., 2017).

The role of emergency management in Turkey is defined as directing emergency calls in case of any health condition and providing organization in case of disaster (Official Gazette of Turkey, 2014). Within the scope of natural disasters and emergency health situations, emergency management and response times have been important issues addressed on a national scale, and various types of research have accelerated in this field. Ozbek et al. (2015) presented a disaster and emergency assessment study in Istanbul to determine the response time and organization of the emergency call in emergency management. In another study, ambulance demand areas were identified using the location-allocation method and location problem optimization model to decrease ambulance response times in the Odunpazarı district of Eskişehir (Swalehe and Aktas, 2016).

The aim of the study is to arrive at the area in the shortest time by using the most appropriate route, differing according to the road characteristics of the ambulance during an emergency.Additionally, unlike regular cars, there are speed limits and safety lane information on the developed software. Former navigation applications used by emergency teams during emergency response do not include variables affecting real-time traffic conditions in routing solutions, such as work and school start/close hours, holidays, weather conditions, and seasonal effects. These shortcomings result in delays in emergency response processes that may even become a matter of life or death in times of crisis. For these reasons, applications that process real-time traffic information and provide routing and estimation based on different vehicle types are required.

Traditional navigation solutions, it is not possible to respond to an emergency immediately. In this study, an approach has been developed to shorten the response time of emergency vehicles in case of any natural disaster or health. Moreover, this study produces alternate routes with navigation based on the real-time traffic. The application development process that makes routing and the features of this application are explained by considering the road attributes and speed times.

2. Methodology

The proposed navigation solution consists of vehicle-based traffic and road network data. Vehicle-based traffic data enables the identification of priority vehicles such as ambulances and fire trucks. Road network data contains road attributes for priority vehicles. The proposed system combines the learned vehicle type behaviors with traffic data and road attributes to make privileged emergency routing according to the vehicle type.

Machine learning methods are utilized to classify vehicle behavior inference and classification using vehicle tracking data to distinguish vehicle types. The data of each vehicle is recorded from the vehicle tracking system as source ID, data date, GPS data (altitude, latitude, longitude), speed, and angular direction (Figure 1). Then, a matrix is created based on acceleration behaviors to distinguish vehicle types. The model is trained using convolutional neural networks (CNN) with vehicle tracking data generated according to classified vehicle types by acceleration behaviors, and vehicle-based traffic data is generated. Vehicle tracking data with unknown vehicle types are processed and classified by the model, and vehicle tracking data classified according to vehicle types is created (Figure 2).

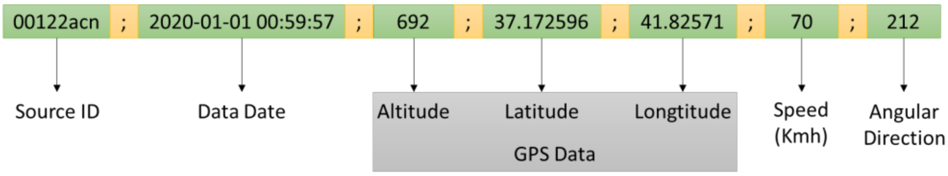

Figure 1 Vehicle tracking system data structure

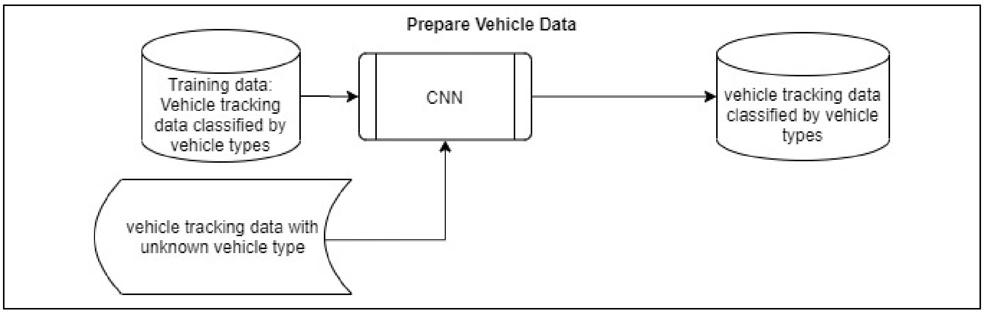

Figure 2 Preparing vehicle tracking data

The system, which learns the behavior of the vehicle types, matches this information with the road attributes and real-time traffic data and makes a privileged routing according to the vehicle type. In this context, attribute information regarding the right of way, presence of safety lane, road width, corner turning angles, and flexible traffic are used from road network data for vehicles such as ambulances and fire trucks. The calculated vehicle-based traffic data and the network data attributes are run with the optimization and routing library algorithms. A route is created between the location of the incident/crime and the emergency vehicle and displayed on the shared map (Figure 3).

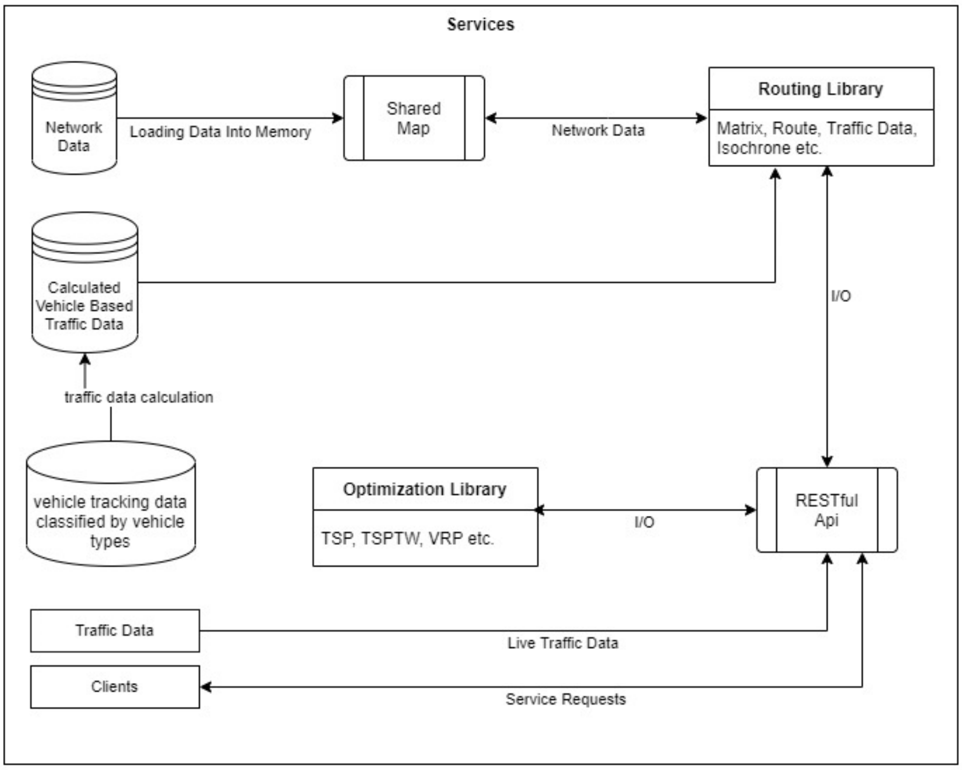

Figure 3 Routing process of the emergency navigation

3. Results

The model has been tested with real-time traffic data, including a busy route in Ankara, the capital of Türkiye. A route was created between Ankara City Hospital and a randomly selected point in the residential area to the west of the hospital, passing over Dumlupınar Boulevard (Figure 4). The safety lane on Dumlupınar Boulevard is the main reason for choosing this route, and the safety lane was used for the emergency vehicle while creating the route. Planning has been done under the road speed limit (80 kph) in order not to cause a security violation.

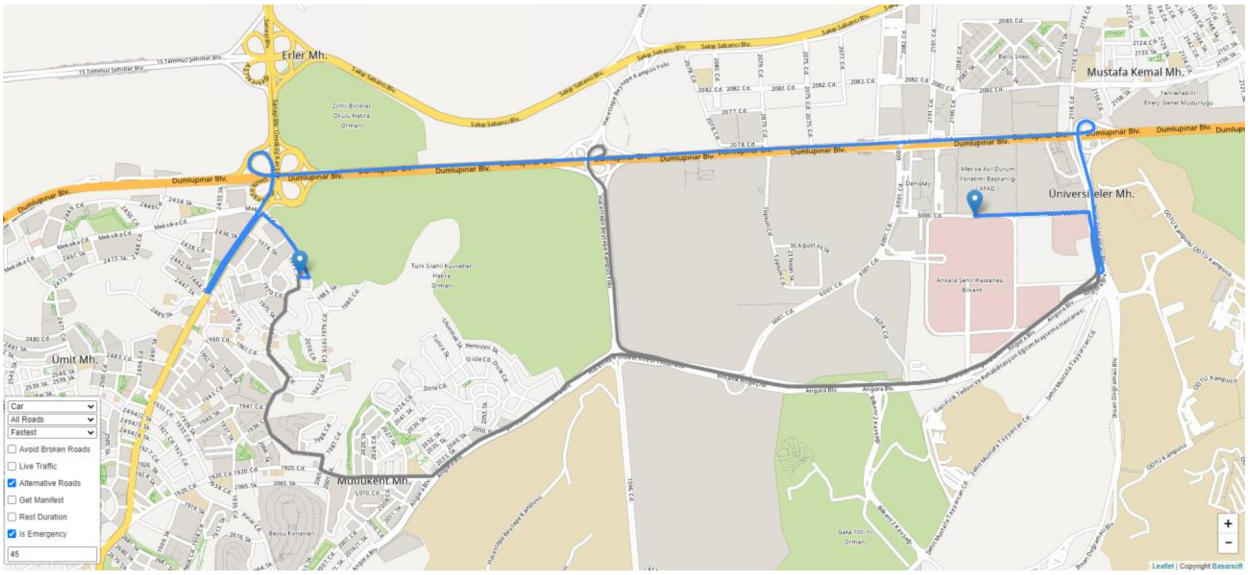

Figure 4 The test route

For the standard and emergency vehicles, the route from the hospital to the selected location and vice versa was calculated. The route from the hospital to the selected location is 8.5 km, and from the selected location to the hospital is 6.2 km. The route in total is 14.7 km.

The results reveal that a ride for a standard vehicle from the hospital to the selected point takes 16 minutes, and 14 minutes is required to return from the selected point to the hospital. The standard vehicle route is calculated as 30 minutes in total. On the other hand, the route created for the emergency vehicle needs a ride of 14 minutes from the hospital to the selected point and 11 minutes backward. The standard vehicle route is calculated as 25 minutes (Table 1).

Table 1 The comparison of the route times of a standard and emergency vehicles

	Standard Vehicle	Emergency Vehicle	Distance
From hospital to selected location	16 min	14 min	8.5 km
From selected location to hospital	14 min	11 min	6.2 km
Total	30 min	25 min	14.7 km

According to the results, a time saving of 5 minutes was achieved on the 14.7 km route calculated for the emergency vehicles, considering the vehicle behaviors and network attributes. In accordance with the study goal, emergency response time was reduced.

4. Conclusion

This study aims to develop a routing approach for emergency vehicles in emergencies. In this context, a route optimization solution specific to emergency vehicles has been made by determining vehicle types, generating traffic data based on vehicle types, and using road network attributes. The model, tested on a busy route in the capital city of Türkiye, enabled a reduction of 5 minutes for emergency vehicles on a route of 14.7 km compared to standard vehicles. Arriving at the emergency location faster is of great importance in reducing death rates in some life-or-death situations. In emergency situations, privileged routing based on vehicle type according to road attributes will also improve urban emergency management.

This paper's main contribution is presenting an empirical approach to emergency management systems in urban areas. During a disaster or health risk, the timely response of emergency vehicles is vital. Emergency vehicles are expected to respond quickly to emergency calls and effectively use urban roads in these situations. With this aspect, this study presents a novel approach to creating efficient and fast routes for emergency vehicles to the disaster/emergency areas.Furthermore, this study reveals that network approaches contain information about emergency vehicles such as ambulances and fire trucks and present a privileged routing approach according to road characteristics in emergency situations.

In future studies, future traffic and emergency predictions can be made by evaluating holiday times, weather conditions, and seasonal conditions, where emergency scenarios occur more frequently. In addition, accident/incident/crime locations can be used as calculation inputs in the decision of the location of the points where emergency vehicles will be dispersed so that emergency vehicles can respond faster. Moreover, vehicle type-based traffic data can determine accident black spots and parking areas. With this information, smart zones can be created. In these smart zones, deceleration/acceleration warnings can be made in the routing manifests in places that require low speed, such as the school zones. With smart zones, routing can also be optimized for parking areas. Finally, road network updates can be made with vehicle type-based traffic data.

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