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Enhancing Road Safety through Automatic Accident Detection and Notification Systems: case of Kigali-Rwanda

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Abstract

Accidents continue to be one of the major causes of death worldwide, as reported by the World Health Organization (WHO), claiming up to 1.2 million lives. Faster emergency responses are a major factor in increasing the survival rate in road accidents. In Rwanda, accidents pose a challenge to public health as a leading cause of death in hospitals that also present a burden to the economy. This research proposes a comprehensive road accident detection and notification system utilizing an in-vehicle Internet of Things (IoT) module equipped with sensors and a sophisticated computer learning algorithm to gain data from intelligent transportation systems (ITS). The proposed system enhances road safety by leveraging real-time data analysis and faster accident response times. The system detects accidents using IoT module which sends data to be processed by computer trained models on patterns from infrastructure based ITS which then triggers the notification to emergency responders.

Keywords: *Accident detection and notification, road safety, ITS, IoT, Machine learning algorithms*

1. Introduction

Road accidents fatalities claimed 1.19 million humans worldwide, with 92% of fatalities occurring in low and middle-income countries, which accounts for less than 1% of motor vehicles and three times the higher risk of death [1].

An estimated 8,000 people are injured in road accidents in Rwanda each year, accounting for around 600 fatalities. Furthermore, half of all patient deaths occur from accident-related injuries, which account for the greatest number of deaths among hospitalized patients. Kigali has the highest percentage of accidents and many victims [2]. About 50% of deaths from road traffic collisions occur within minutes at the scene or in transit to hospitals in the EU region; that number rises by two to three times in low-income countries. For traffic accidents, emergency care is a series of time-sensitive actions; victims' pre-hospital survival was associated with less than 17 minutes response times in the Accra study [3][4]. The economic cost of accidents is estimated to be around 5% of GDP [1]. Insurance grievances in Rwanda have increased by an average of 15% yearly, signifying the economic burden on the country's development [5]. The economic development and infrastructure expansion gave rise to an escalating concern for road accidents; the age of vehicles on roads also signifies the concern due to the lack of modern advanced safety systems in vehicles [6].

Jullie Lahousse [7] conducted a predictive study to investigate the potential of accident notification systems in reducing fatalities and concluded that they have helped to reduce fatalities by 11%. Simple systems requiring only mobile phones and well-designed protocols can also greatly improve care [8].

The absence of an Automatic Accident Detection and Notification System (AADNS) created especially for Rwanda adds to these issues. Through the utilization of sensor networks, real-time data, and communication technologies, AADNS holds the potential to improve the way the country tackles road safety. However, the absence of a comprehensive AADNS tailored to the Rwandan context emphasizes the urgency with which this topic requires to be investigated and developed further.

This research aims to bridge this significant gap by examining the practicability, possible uses, and benefits of implementing Automatic Accidents Detection and Notification Systems in Rwanda. By undertaking this action, we intend to encourage further efforts to improve traffic safety initiatives, reduce the number of fatalities brought on by accidents, and pave the way for Rwanda to have a safe and sustainable development for the population of Rwanda.

2. Background

The number of studies concerning automatic detection and emergency systems has improved significantly regarding technology and response time. The rapid range from using advanced technologies powered by artificial intelligence and machine learning to simple IOT in-vehicle installation kits that communicate with dispatching centers. Modern vehicular technology also incorporates advanced notification systems during accidents and infrastructure-based technologies intelligent transportation systems (ITS). For example, Abdul Mateen and Muhammad [9] used a smart road concept by equipping roads with systems that have multiple sensors that detect sounds, light, and smoke and directly send information and location to the emergency operation center. However, the system was only tested in a laboratory and has short-range sensing capabilities where nodes must be 50m apart forefficient results. Mohamed Iqbar [10] implemented an ITS- based system using smart traffic systems at signalized intersections; the study did not address further applications in connecting the ITS systems to emergency responders using IoT-based applications. In addition to infrastructure-based systems, Sajal et al. [11] used advanced computational frameworks that detect and forecast accidents by modeling patterns from CCTV cameras installed on road networks.

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Hireche and Dennaai [12] reviewed different machine learning techniques in detecting accidents using fixed traffic monitoring technology and concluded that the techniques yield high accuracy rates at about 98%. Using computer vision and artificial intelligence Nikhlesh Pathik et al. [13] developed an enhanced deep learning model to alert emergency responders, however the model faced challenges of dataset unreliability which can be improved by using existing traffic monitoring intelligent systems. Ashwin et al. [14] explored using a black box in the vehicle, which detects and transfers messages to emergency rescue services. The emergency rescue services get the message from a mobile-developed application incorporating an abort function in case of false alerts. The advances of mobile devices have opened possibilities due to their portability and built-in sensors. Prashant and Shubham [15] developed a mobile application software that communicates with emergency services operation centers; the application takes advantage of advanced embedded components and sensors such as GPS and gyro meter.
However, the application depends on the availability of the internet connection, which becomes a challenge in case of a lack of network signal. Hamid and Zainab [16] went on to use smartphones to not only provide notification to first responders but also to give them pictures and videos at the location for an advance dispatch; their work also provided options for drivers to cancel alerts when there are false flags to increase the system reliability. Jules et al. [17] developed a mobile application and an algorithm to filter data from sensors to ensure that false positives are reduced; the study concludes that smartphones cannot possibly detect all accidents. Vehicle-to-vehicle communications also provide solutions to accidents and rescue notifications. Mubashir and Sanaullah [18] propose a system that applies distance sensors to keep safe distances between vehicles and send instant alerts in case of vehicle collision.
From the literature on accident notification systems, it is evident that systems to be more effective the combination of road monitoring systems using ITS and vehicle integrated IoT modules help to increase reliability and robustness of road accidents, a more interoperable approach can yield enhanced result in improving road safety.

3. Proposed system

The proposed system in this study seeks to utilize a hybrid framework by combining the best available systems and leveraging each system's advantages for more reliability and to improve post-accident care in Kigali-Rwanda. The system comprises three integrated solutions, making it effective and efficient in monitoring and ensuring accident detection and timely response with the emergency responders who understand the accident scene and prepare accordingly.

The system has an in-vehicle IoT module equipped with sensors that can be paired with the driver's smartphone if the driver has one; the module is used for accident detection. advanced computer learning algorithm can then be used to detect emergency systems, and the algorithm will be trained on infrastructure-based intelligent transportation systems (ITS).

The in-vehicle IoT module can detect and sense the vehicle's parameters during the accident. Those parameters include pressure. sensor to measure the force during the collision, sonic sensors for sound threshold measurement, and a camera to capture pictures and videos of the vehicular surroundings; the camera provides insights into the nature of the accidents to responders beforehand, thus making the rescue plan effective. The system should also be equipped with GPS for location precision and a GSM module to initiate communication during the collision. If the driver has a smartphone, it can be paired with the in-vehicle IoT module using a Bluetooth or Wi-Fi connection. This allows the smartphone to receive accident detection alerts and/or emergency notifications.

If the module detects an anomaly that suggests an accident, it triggers the accident detection process. It sends an alert to the driver's smartphone and the infrastructure-based intelligent transportation systems (ITS).

The system applies an advanced computer learning algorithm that is trained on a large dataset of data collected from infrastructure based ITS systems such as road cameras and traffic light signals. The dataset includes information about accidents, road conditions, and traffic patterns. The algorithm analyzes this data to identify patterns that are indicative of accidents and then triggers a notification to nearby emergency services. For the system to be effective the infrastructure-based intelligent transportation systems (ITS) should be integrated in to communicate with infrastructure-based intelligent transportation systems (ITS) continuously. This allows the system to receive real-time information about traffic conditions, road hazards, and emergency services. Moreover, the fusion of the two systems can help gain a full understanding of the situation and help improve the post-accident care system.

4. Conclusion

The proposed integration of in-vehicle IoT modules with advanced algorithms ensures a proactive and effective response to road accidents, contributing to reduced response times and improved outcomes in emergency situations. The system application in Rwanda puts together the advent of using cheaper and smaller components that have resulted in portable and adequate products for mass data collection, coupled with infrastructure data and modern, powerful computer algorithms, making an effective tool to enhance road traffic safety. Further research and implementation are essential to validate the system's efficacy in delivering expected outcomes and its reliability in real-world scenarios. Further, the cost-benefit analysis of the system is also imperative to understand its effectiveness and an applicable approach for adoption between the government of Rwanda and vehicle owners.

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