DEVELOPMENT OF A ROAD ACCIDENT SIMULATION FOR AUTOMATIC ROAD ACCIDENT REPORT SYSTEM

Keyword: Road Simulation, Accident Analysis,Human–Environment Interaction, Road Safety, Systems Theory

Abstract

Road accidents have become a crucial problem in Labo, Camarines Norte. Many road accidents happen because of lack of street lighting or the poor lighting, slippery roads, blind curves, and careless, sleepy, and tired drivers due to the longest highway that Labo has. This simulation study aims to develop a Road Accident Simulation and Automation Report System that can help predict and analyze accidents before it will happen. The Simulation Model uses math and physics formulas to recreate how accidents occur based on real factors that cause road accidents like vehicle speed, road condition, and angle of impact.

This study is guided by System Theory, which says that accidents happen because of the interaction between drivers, vehicles, roads, and the environment and not just one single cause. By studying these relationships, the simulation can help identify which are the dangerous areas around the place and test safety improvements, such as adding street lights or installing warning signs. As a result, this system will help local authorities in Labo, Camarines Norte make better plans to improve road safety and prevent future accidents.

Introduction

Road accidents are becoming a serious problem in Labo, Camarines Norte. Many accidents happen because of dangerous intersections, blind curves, and long highways.Some drivers also meet accidents for the reason that they are not familiar with the road, while others lose control due to slippery roads or dark areas with little or no street light. While in some cases, accidents occur when drivers become sleepy or tired, experience mechanical problems, and a lot accidents happen because of the drivers under the influence of alcohol. Currently, there are no local tools to predict where and how accidents might occur, making it difficult for local authorities to prevent them. This study aims to develop a Road Accident Simulation and Modeling System for Automatic Road Accident Report System that can illustrate the possible accident scenarios. By using this system, we can understand the effects of vehicle speed and traffic lights on road safety and suggest strategies to reduce accidents.

Previous research has shown that simulation plays an important role in improving road safety. [1] published study developed a 3D road accident simulator that automatically generates accident reports and predicts driver responsibilities using machine learning. As a result, the system showed that simulations can produce realistic accident scenarios, generate training data for image recognition, and support authorities in managing accident information.

In another related study [2] published. It is about Statistical Mechanics and its Applications, the researchers used cellular automation to model and simulate car accidents at signalized intersections. It showed how traffic patterns and accidents can be analyzed with the use of simulation, which can provide predictions that will improve for traffic safety. This is relevant to the current study because it shows that even complex traffic interactions can be modeled to anticipate accidents, which is the principle applied in developing a local system for Labo, Camarines Norte.

By developing a simulation system and automatic road accident report, the local government and traffic authorities in Labo, Camarines Norte can create better plan safety strategies, such as improving street lighting, placing warning signs, and controlling vehicle speed in areas that are more likely to have accidents. This study aims to help residents and commuters stay safe by increasing awareness and improving road safety. While accident-prone areas can be closely monitored and managed. The system will serve as a useful tool to predict and prevent accidents, specifically the road safety problems in Labo, Camarines Norte.

Literature Review

Road safety has always been a major concern in many local areas Camarines Norte, where accidents are often caused by dangerous intersections, blind curves, slippery and dark roads, and careless and sometimes sleepy drivers due to long highways. To reduce the risk of road accidents, it is important to identify the locations that are more likely to have accidents and also it's very important to understand the factors that cause them. Recent studies have shown that simulation and modeling can be very useful tools in predicting and preventing road accidents. Researchers and engineers study different ways to identify dangerous areas and understand the causes of accidents to prevent road accidents. These research works provide valuable ideas that can help the future researcher and applied in developing the Road Accident Simulation and Modeling, which aims to help authorities monitor, analyze, and reduce accidents in the area.

The System Theory, introduced by Ludwig von Bertalanffy in 1968 explains that everything works as part of the whole system is made up of connected parts that can affect one another. When we apply it to road safety, this theory gives an idea that suggests accidents don't happen because of a single cause. Instead, they result from the interaction of several factors, such as the driver, the vehicle, the road condition, the weather, and even the traffic laws. Each of these components make up what is known as the Road Transport System (RTS), where the changes in one element can affect the others. In this development study, System Theory serves as the foundation for understanding how road accidents occur in Labo, Camarines Norte. By using simulation and modeling, it aims to analyze how different factors work together to create high-risk situations. This approach reflects the idea that improving road safety requires looking at the system as a whole rather than focusing on just one part. Within any system, the interconnectedness ensures that even the smallest change in one element can influence everything.

Simulations can demonstrate different factors working together to increase the risk of accidents. By identifying these patterns, local authorities can plan and design more effective interventions, such as adding more street lights, placing warning signs in blind curves, or enforcing speed limits to help prevent accidents and improve overall road safety. In the study of Hu (2024) which entitled *Estimating Accident-Prone Freeway Sections: Simulation and Accident Prediction Model*, they worked on identifying the most dangerous parts of a 77-kilometer freeway in Zhejiang Province, in China. They collected data about previous accidents and the physical structure of the road, such as its curves and the slopes. Two main statistical methods are shown in their studies , the improved cumulative frequency method and the accident matrix method were used to find which sections had the most accidents.

They also developed a new method that combined vehicle dynamic simulation using the CarSim software and speed consistency theory to estimate and understand accident-prone areas more accurately. Through this approach, they developed an accident prediction model that allows engineers to better understand how the road design and driver behavior can influence safety. The model can also be used to assess the safety of new road layouts before they are constructed. This is connected to the current study, as the proposed system in Labo also aims to use simulation to identify high-risk areas and support improvement of local road design and safety plans.

In a similar study, Cheng (2022) examined vehicle- pedestrian accidents using simulation and measured the risk of injury through the Head Injury Criterion (HIC). The results showed that factors such as vehicle speed, collision angle, and vehicle can greatly affect how severe an accident can be. This research supports the idea that simulation can be a useful tool for identifying risk factors and testing safety measures.

In another related study, Kizito (2020)explored the cause of road accidents through their research entitled Modeling the Complexity of Road Accidents Prevention: A System Dynamics Approach. They viewed accidents as a part of a larger system known as the Road Transport System (RTS) . Instead of blaming only the drivers, their findings showed that accidents are caused by many connected factors such as road conditions, vehicle maintenance, traffic management, and human behavior which is also connected to the System Theory. Their study used Dynamic Synthesis Methodology (DSM) to analyze these interactions and develop models showing how accidents happen before a crash occurs. Data from police, road users, and engineers helped them identify the main areas where safety interventions could reduce accidents. This approach relates to the Simulation and Modeling of a Road Accident in Camarines Norte because it also recognizes that accidents are not just caused by a single factor. By considering human error, road design, lighting, and environmental conditions, the simulation and modeling to be developed will adopt a multi-factor approach similar to Kizito and Semwanga's model to analyze local conditions and predict where accidents are likely to occur.

Additionally, in the paper published “AI and IoT-Based Road Accident Detection and Reporting System” by Patil et al., (2023), the study introduces a system that combines vibration sensors, accelerometers, alcohol sensors, GPS, camera, and Raspberry Pi to detect collision. Once there’s an accident, the system will automatically send data to the cloud for reporting and enable a faster emergency response. Similarly, Akshatha (2017), in their study “Automatic Accident Detection and Intelligence Navigation System” proposed a system that not only detects accidents but also guides an ambulance to the nearest hospital using an intelligent navigation feature. The system will help prevent delays caused by traffic congestion by transmitting the accident’s GPS location and the victim’s information to hospitals and ambulances through the use of e-NOTIFY system, using vehicle-to-vehicle communication to clear routes for emergency transport.

Moreover, combining the machine learning techniques with three-dimensional simulation environments has become a powerful way to predict and analyse road accidents. Yawovi (2020) developed a system based on advanced Random Forest algorithms that could automatically generate detailed accident reports and accurately predicted driver responsibilities. Their simulator generated realistic and complex accident scenarios that can give a lot of purpose, including training image recognition models and providing valuable information for accident management teams. With the use of this system it made accident data more accurate and complete, it can also reduce the need of manual analysis. Overall, the study shows how the use of data-driven machine learning and advanced simulation can fill important gaps in accident prediction and offer practical tools that can make roads safer.

All of these studies have the same goal. Which is to make the roads safer through the use of advanced technologies such as simulation, data modeling, automation, and artificial intelligence. With the help of these previous studies, analyzing data and simulating or understanding the different scenarios, researchers can better understand how and what are the possible reasons why accidents happen and what can be done to prevent them. For Labo, Camarines Norte, where many accidents happen due to slippery roads, blind curves, and poor lighting, adopting these approaches will be very important toward developing a Road Accident Simulation and Modeling System. This system will not only help predict where accidents are likely to occur but also test the effectiveness of safety measures such as improved street lighting, better signage, and stricter law enforcement ultimately helping create safer roads and protect the lives of local residents.

MATHEMATICAL MODEL PROCESS

This development uses two linked models to turn real-world accident factors into clear, testable results. The first Model is the Simulation; it recreates the physical events of a crash using physics and motion equations. The second model is the Reporting; it will turn the simulation's raw numbers into a readable, structured accident report. Below is a brief, human-friendly mathematical description of how those models work together and the main formulas they use.

Overview of the Process

1. **Collect Input Data – Start by gathering important details such as the speed of each vehicle, their weight, the angle of impact, the condition of the road (like how slippery it is), lighting, and the drivers' reactions before the crash.**

2. **Run the Simulation Model (Model 1) – Using the collected data, the system calculates how each vehicle moved before the crash, what happened during the collision, and how they behaved afterward. It applies mathematical principles like momentum and energy to make the simulation realistic.**

3. **Generate Raw Results – After the simulation, the system produces data such as the final positions of the vehicles, their speeds after the collision, the force of impact, their movement paths, skid marks, and the timing of each event.**

4. **Run the Reporting Model (Model 2) – The raw data is then analyzed and converted into a clear, human-readable report. This model identifies what type of accident occurred (for example, a rear-end collision) and rates its severity based on the simulation results.**

5. **Validate and Refine – Finally, the simulated results are compared with real-life accident data, if available. Adjustments are made to improve the model's accuracy and reliability for future simulations.**

Model 1: The Simulation Model

The use of this model is to simulate what happens during a road accident with the use of mathematical formulas. It uses input data such as vehicle speed, weight, angle of impact, and road conditions. The output of this model includes numerical results like the vehicle's final position, the force of impact, and the direction the vehicles moved after the crash.

Mathematical formulas such as:

- **Displacement: d=vit+12at2d = v_i t + \frac{1}{2}at^2d=vit+21at2**

- **Final Velocity: vf=vi+atv_f = v_i + atvf=vi+at**

- Momentum Conservation: m1v1i+m2v2i=(m1+m2)vfm_1v_{1i} + m_2v_{2i} = (m_1 + m_2)v_fm1v1i+m2v2i=(m1+m2)vf

These will help calculate how vehicles move, brake, and collide. The principle of conservation of momentum is especially important because it shows that the total momentum before and after the crash remains the same, even though energy is lost during impact.

Model 2: The Reporting Model

Once the simulation produces the raw data, the reporting model processes this information to create a clear, human-readable report. It automatically writes a summary of the accident, includes diagrams, and classifies the type and severity of the collision.

This model uses decision rules and state logic to describe what happened:

- For example:
    - *If* the front of one car hits the rear of another, *then* it's a "rear-end collision."
    - *If* the change in speed is very high, *then* the crash severity is "high."

By using and combining these models together, the system can both simulate and explain an accident accurately. This makes the process faster, reduces human error, and helps authorities analyze the causes of road accidents more effectively.

RESULTS AND DISCUSSION

The Development of the Road Accident Simulation for Automatic Road Accident Report System shows results about how road accidents can be modeled and analyzed using real-world data. Through the use of simulation modeling and automated reporting, the study showed that accidents are the results of multiple interacting factors such as vehicle speed, road conditions, lighting, and even the driver behavior. The primary result is the creation of a functional tool that can transition from complex input data to clear and actionable safety reports that can surely help in Labo, Camarines Norte.

Simulation Outcomes

The application of simulation model, in which applies basic formulas for motion and momentum m1v1i+m2v2i=(m1+m2)vfm_1v_{1i} + m_2v_{2i} = (m_1 + m_2)v_fm1v1i+m2v2i=(m1+m2)vf , produced accurate and realistic results for simulated road accidents. This model will help determine the risk factor with regards to Road Accidents in Labo, Camarines Norte such as the vehicle speed, poor road conditions, and angle of impact into measurable data. The output, including the post-impact speed, final position of the vehicles, and a force of collision, provide a clear representation on how severe an accident can be. The simulation's ability to compute it produced measurable results that closely resembled actual accident patterns.

LITERATURE REFERENCE

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