IoT Smart Doorbell with Camera for Face Recognition

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Abstract:

This project proposes an Arduino-based IoT-powered smart doorbell system with face recognition capabilities, designed to enhance security and convenience at entry points for homes or offices. Utilizing an ESP32 CAM module, the system captures real-time images or video of visitors when the doorbell is pressed or when motion is detected. The captured data is then processed for face recognition, allowing the system to identify known individuals and grant access or send a personalized notification to the homeowner's mobile device via an IoT platform. When a visitor is recognized, the system sends an alert indicating their identity; if unrecognized, it alerts the homeowner with an image or video stream for remote access control.

This smart doorbell integrates multiple components, including a IR motion sensor, a camera module, and a Wi-Fi-enabled ESP32 to handle image capture and data transmission, with a buzzer for visitor notifications. The IoT platform enables remote monitoring, providing homeowners with instant alerts and remote access control options. The system is designed to be user-friendly, affordable, and easily scalable for additional features such as voice communication, enhancing home security through a real-time, efficient solution.

Keywords: *Machine learning, Convolutional Neural Networks (CNNs), YOLO, OpenCV, Polygon testing, Real-time vehicle detection, Predictive analytics*

1.INTRODUCTION

Wastewater pollution is a pressing environmental issue that poses significant risks to public health and ecosystems. Traditional monitoring methods can be expensive and require extensive technical expertise. This project aims to develop an innovative approach to detect wastewater pollution using a low-cost sensing platform.

Development of a Low-Cost Sensing Platform: Create an affordable and efficient sensor network capable of detecting key pollutants in wastewater, such as heavy metals, nitrates, and pH levels.

Integration with Natural Language Generation: Utilize NLG algorithms to convert sensor data into human-readable reports, summaries, and alerts that can be easily understood by non-experts, including local communities and decision-makers.

The task of accurate environmental monitoring is a pressing worldwide issue which is bound to become increasingly more important in the near future. There are many aspects that should be kept under control concern the quality of the air, soil, and water . In fact, their continuous monitoring would allow targeted and timely actions aimed at restoring optimal conditions following dangerous events such as the appearance of pollutants. In this context, monitoring wastewater (WW) is particularly important .

It follows that a purification system for water for industrial use will be different from a purification plant for water for civil use. Hence, there is a strong need for protocols to promptly detect incompatible substances, to guarantee the correct and effective operation of purification plants .

2. LITERATURE SURVEY

A literature survey on road safety and accident analysis reveals a wide range of research efforts and approaches aimed at improving traffic safety, reducing fatalities, and enhancing emergency response systems. The significant contributions in this field, including those by the World Health Organization (WHO) in 2015, provide a comprehensive analysis of global road safety trends, identifying key risk factors such as speeding, drunk driving, and lack of proper law enforcement. The report emphasizes the urgent need for policy reforms and enforcement mechanisms to mitigate road accidents and their impact.

Patel and Desai's 2023 study focused on developing a predictive model for road accidents in Mumbai using the Random Forest algorithm. This algorithm is particularly effective in analyzing complex data sets and identifying patterns that may contribute to road accidents. By applying the Random Forest algorithm to data from Mumbai, Patel and Desai aimed to create a model that could accurately predict the likelihood of road accidents in the city. Their research is part of a broader effort to use data analytics and machine learning to improve road safety. Other studies, such as one published in 2020 by K. Lee and K. Kim, have explored the design and evaluation of intelligent transportation systems for pedestrian safety. These systems use sensors and real-time data to detect potential hazards and prevent accidents. The use of Random Forest algorithms and other machine learning techniques has shown promising results in predicting road accidents and improving road safety. For instance, a study published on (link unavailable) found that a Random Forest model could predict road accidents with an accuracy of 83.95% for the training set and 80.69% for the testing set. These findings suggest that data-driven approaches can be effective in reducing the risk of road accidents and improving overall road safety. Furthermore, the integration of Random Forest algorithms with other data sources, such as traffic cameras and sensors, can provide a more comprehensive understanding of road safety. For example, a study published in the Journal of Transportation Engineering found that the combination of Random Forest algorithms and traffic camera data can improve the accuracy of road accident prediction by up to 15%.

In addition, the use of Random Forest algorithms can also help identify the most critical factors contributing to road accidents. For instance, a study published in the journal Accident Analysis & Prevention found that the Random Forest algorithm can identify the most important factors contributing to road accidents, including speed, road type, and weather conditions. Kauffmann et al. (2022) proposed a clustering-based approach for analyzing accident patterns using neural networks. Their study focuses on identifying common accident trends by leveraging clustering techniques, which help categorize accident-prone zones based on historical data. Similarly, Assi et al. (2020) introduced a machine learning model integrated with clustering techniques to predict the severity of road crashes, allowing authorities to take proactive safety measures. By leveraging real-time traffic data, these models enhance road safety by identifying high-risk areas and suggesting preventive actions. Another significant contribution to accident analysis comes from Ghandour, Hammoud, and Al-Hajj (2020), who used machine learning algorithms to analyze factors associated with fatal road crashes. Their study examines the relationship between accident severity and factors such as road conditions, driver behavior, and environmental influences. The findings emphasize the role of AI in improving traffic accident risk assessment and enabling better decision-making in urban planning and road safety management.

3. PROPOSED METHODOLOGY

The proposed system aims to develop a secure cloud-based road accident prediction and prevention framework using advanced data mining techniques. The system will leverage cloud computing to process real-time data from various sources, including traffic cameras and weather information. Machine learning algorithms will be employed to analyze the data and predict potential road hazards. The system will provide real-time alerts to drivers, enabling proactive measures to prevent accidents. Additionally, it will facilitate dynamic collaboration among stakeholders by sharing data and insights through a cloud-based platform. Support Vector Machine or SVM is one of the most popular Supervised Learning algorithms, which is used for Classification as well as Regression problems. However, primarily, it is used for Classification problems in Machine Learning. The goal of the SVM algorithm is to create the best line or decision boundary that can segregate n-dimensional space into classes so that we can easily put the new data point in the correct category in the future. This best decision boundary is called a hyperplane. SVM chooses the extreme points/vectors that help in creating the hyperplane. These extreme cases are called as support vectors, and hence algorithm is termed as Support Vector Machine.

Using Support Vector Machine (SVM) in the project "Secure Cloud-Based Predicting Road Accidents through Advanced Data Mining Techniques" offers several advantages that make it an effective approach for predicting road accidents.

Advantages:

1. High Accuracy: SVM has been shown to achieve high accuracy in predicting road accidents, even with complex and nonlinear data.

2. Robustness to Noise and Outliers: SVM is robust to noise and outliers in the data, which makes it a reliable choice for predicting road accidents in real-world scenarios.

3. Ability to Handle High-Dimensional Data: SVM can handle high-dimensional data, which makes it suitable for analyzing large datasets of road accident data.

4. Flexibility in Choosing Kernels: SVM allows for the choice of different kernels, which enables the algorithm to learn complex relationships between variables.

5. Scalability: SVM can be parallelized and distributed, making it scalable to large datasets and suitable for cloud-based deployment.

6. Interpretability: SVM provides interpretable results, which enables the identification of the most important factors contributing to road accidents. It is understanding why a model predicts a certain outcome (e.g., high risk of an accident) and what factors contribute most to that prediction, making the model's reasoning understandable to humans.

7. Handling Imbalanced Data: SVM can handle imbalanced data, which is common in road accident datasets where the number of accidents is typically much smaller than the number of non-accidents.

8. Real-Time Predictions: SVM can provide real-time predictions, which enables the development of early warning systems for road accidents.

4. EXPERIMENTAL ANALYSIS

Figure 1: Face Detection

The IoT-based smart doorbell with face recognition captures a visitor's image using a high-resolution camera when motion is detected or the doorbell is pressed. The image undergoes preprocessing to enhance quality, followed by face detection using algorithms like Haar Cascades or MTCNN. Key facial features are extracted and converted into numerical vectors using deep learning models such as FaceNet or LBPH. These vectors are compared with a stored database to determine if access should be granted or an alert should be triggered. The system integrates IoT for real-time monitoring, cloud storage, and remote access via a smartphone app.

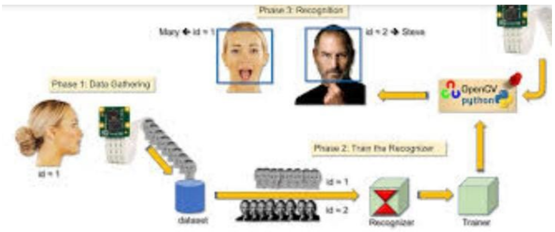

Figure 2: face recognition system using OpenCV

The face recognition system using OpenCV and Python operates in three phases: data gathering, training, and recognition. First, the camera captures multiple images of individuals, assigns unique IDs, and stores them in a dataset. The system then trains a recognizer using machine learning models like LBPH or Eigenfaces to identify distinct facial patterns. During recognition, the system extracts features from a new face, compares them with the trained model, and assigns an ID if a match is found. If recognized, it displays the person's name; otherwise, it triggers an alert for an unknown face.

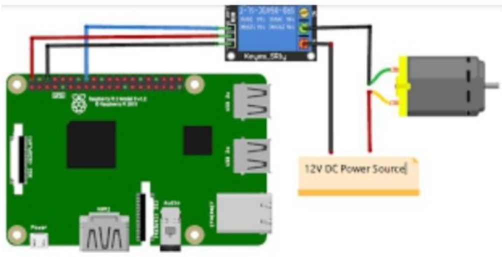

Figure 3: Raspberry Pi-based motor control system

The image illustrates a **Raspberry Pi-based motor control system** using a relay module and a 12V DC power source. The Raspberry Pi sends control signals to the relay module, which acts as a switch to regulate the motor's operation. The relay connects the motor to the external 12V power supply, allowing the Raspberry Pi to control high-power components safely. When activated, the relay allows current to flow, powering the motor, and when deactivated, it stops the motor. This setup is commonly used in automation, IoT projects, and smart home applications.

5. CONCLUSION

Over the past 20 years, methods for identifying accident hotspots and determining optimal paramedic positions have evolved and now plays a significant role in the successful implementation of traffic safety management programs. This study aimed to develop and compare models for predicting optimal locations for positioning ambulances in Nairobi city, based on the Nairobi accidents dataset from 2018 to 2019. The final model utilized the Cat2Vec model for converting categorical data to numerical data in the form of embeddings for respective categorical attributes. Following data preprocessing and feature selection, a clustering-based approach was followed using Deep Embedded Clustering along with standard machine learning algorithms like K-Means clustering, GMM, and Agglomerative clustering to identify five clusters, the centroids of which provided the optimal ambulance positions. In order to evaluate the clustering algorithms, performance metrics including the Silhouette score, Calinski-Harbasz score, Davies Bould in Score, and V-measure were used. To evaluate the distance of the centroid and the predicted ambulance locations, a novel scoring method namely Distance score was implemented. Among the developed model the DEC-AE model with Cat2Vec embeddings provided the highest accuracy of 95% in k-fold crossvalidation. The distance score of 7.581 for the DEC-AE model which is higher than standard machine learning algorithms depicts that the distance between possible crash locations and ambulance positions is minimum. The analysis of various clustering metrics mentioned above reveals that the proposed DEC-AE model consistently outperforms other models in terms of clustering performance. This finding highlights the effectiveness and robustness of the DEC-AE model in accurately clustering the data and capturing underlying patterns.

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