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i-Carelift-IoT Based Smart Elevator for a Healthcare Facility

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***Abstract* - The goal of this research project was to create a novel algorithm that would increase energy efficiency in vertical transportation systems, with an emphasis on elevators, especially during periods of high traffic. We developed a comprehensive strategy for the problem by fusing the sophisticated elevator management system with the capabilities of a mobile application and cutting-edge Internet of Things (IoT) tools. This Internet of Things (IoT) devices drastically reduced the frequently infuriating wait times for elevators in addition to helping to reduce overcrowding problems. Our methodology's strategic coordination of passenger schedules with the implementation of ground- breaking elevator stopping protocols ensured the most efficient use of energy during elevator transitions. We provided three mathematical frameworks to explain these stopping processes. Our study looked at three different methods: a standard protocol that allowed elevators to stop at every floor, a creative odd-even layout where certain elevators only served odd or even floors, and a high-low configuration where elevators were designated to primarily serve either the upper or lower portions of a building. The combination of these tactics has positive ramifications for the development of energy-efficient vertical transportation systems in the future.**

Keywords: SVM, PCA, IoT, F1-score.

I. INTORDUCTION

Elevators have become an integral facet of modern society, finding widespread application in residential buildings, commercial complexes, healthcare facilities, shopping malls, and industrial sites. In the present era, the paramount considerations are optimizing time usage and ensuring safety. Many of the existing elevator systems primarily focus on minimizing wait times and maximizing operational speed. Some specialized industrial elevators integrate authorization modules to enhance security, while others possess post-event emergency detection capabilities, though the efficacy of such retroactive responses is limited. Furthermore, certain systems incorporate alerts to signify mechanical component failures or imminent malfunctions, yet a comprehensive, proactive approach to transforming elevator systems into intelligent, efficient, and secure entities is conspicuously absent.

Elevator management systems within healthcare institutions currently rely on proximity-based algorithms, prioritizing rapid service. In cases of multiple elevators serving a single floor, the closest elevator is summoned to expedite user transport, an approach aimed at reducing wait times. Similarly, RFID tags are employed to authorize specific personnel, such as doctors, for access to designated floors. Consequently, these systems prioritize security enhancements and align with the prevailing trend of minimizing elevator travel durations.

However, in contexts where security concerns are less pronounced, it becomes evident that most of these management systems inadequately account for waiting passengers. Despite monitoring weight limits, these systems often underutilize this information. Furthermore, these frameworks lack systematic approaches for prioritizing waiting passengers and lack comprehensive strategies for managing elevators during emergencies and crisis scenarios.

This paper identifies the existing limitations within contemporary elevator management systems and proposes a novel framework that converges efficiency, security, and emergency responsiveness. Through the amalgamation of advanced algorithms and Internet of Things (IoT) technologies, our approach seeks to redefine elevator systems, enhancing passenger experiences, and effectively addressing potential emergency situations.

II. RELATED WORK

Advancements in Elevator System Efficiency for Healthcare Facilities: Integrating Machine Learning, Improved Passenger Identification, and IoT-based Disaster Alarms. Elevator systems within healthcare environments are critical for ensuring prompt vertical movement of patients, medical

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personnel, and visitors. In response to the intricate demands of these settings, researchers have explored novel avenues to enhance elevator operations. This literature review investigates the progress made in optimizing elevator efficiency for healthcare facilities, focusing on the integration of machine learning techniques, refined passenger identification methods, and the incorporation of an IoT-based disaster identification alarm system.

The current elevator systems in Sri Lankan healthcare facilities do not prioritize user intelligence or convenience. In addition, they use elevators that are common throughout the country and do not have any characteristics unique to healthcare facilities. Even though there is an actual need for a priority-based system, all users are given equal priority. This is inefficient and ineffective in actual situations. Existing elevator systems would benefit greatly from a digital display outside the elevator that displays the number of commuters inside and the average arrival time of the elevator. It will reduce the passengers' waiting time. It is especially vital in a healthcare facility to facilitate users without compromising their physical and mental energy. Therefore, a digital elevator system based on the Internet of Things is essential for managing users in a healthcare facility.

Numerous studies have been conducted, and there are numerous research outcomes in this field. Existing passenger flow monitoring software utilizes computer vision. This study proposes a method for counting passenger flow based on the combination of image processing techniques such as the background subtraction method, the SVM machine learning model, the YOLO3 deep learning model, and others. After identifying the details of the door switch, the system will monitor the present status of the elevator using the background subtraction method with return on investment. This existing system employs Non-Maximum Suppression to detect passengers within the elevator. Even though this existing system can detect passenger count, the system's accuracy is low due to the use of YOLOv3 for identification. Another existing system proposes algorithm research for the identification and monitoring of human bodies outside the elevator door. This system presents a novel approach for elevator door protection based on digital image processing. The human body identification and monitoring system includes detection of moving objects, human identification, and tracking of moving humans, among other components. The system proposes two methods: detection of moving objects based on inter-frame difference and background difference, and identification of the human body based on relative size. This method has been able to propose mathematical functions and output graphs to demonstrate the tests' precision. In addition, the system proposes a method for human body tracking based on the accumulation of contour differences.

Compared to other existing systems, this approach has gone into greater depth regarding the particulars. Another existing method proposed passenger counting based on Haar-like characteristics in elevator applications. A classifier is developed using a statistical method that trains multiple positive samples (with head-shoulder) and negative samples (without head-shoulder). This method modifies Haar-like features and applies them to elevator passenger detection application by training a head-shoulder classifier, with an emphasis on detecting passengers outside the elevator's premises. Since these existing systems lack a component for displaying the inside passenger count and average elevator arrival time, this research component will assist in overcoming their limitations.

Challenges in conventional elevator systems within healthcare settings arise from the diverse user groups, ranging from individuals with disabilities to time-constrained medical professionals. The conventional systems often prioritize speed and proximity, potentially neglecting the equitable access and specialized assistance that are vital in such contexts.

Machine learning has emerged as a powerful tool in addressing these challenges. Recent research endeavors have harnessed machine learning algorithms to leverage historical data, enabling elevators to make informed decisions. These algorithms discern user traffic patterns, predict peak activity times, and optimize travel routes, ultimately reducing waiting times and elevating the efficiency of vertical transportation.

The domain of passenger identification has also witnessed significant progress. Cutting-edge techniques, such as computer vision employing Haar cascades, have allowed for accurate identification and classification of individuals, encompassing disabled patients, doctors, and nurses. This advancement facilitates personalized elevator access for medical professionals and improved accommodation for individuals with distinct mobility requirements.

Moreover, the integration of IoT technology has paved the way for disaster identification capabilities within elevator systems. By integrating sensors and real-time data streams, IoT-driven systems can swiftly detect emergencies such as fires or seismic events. When triggered, these systems activate alarms and dictate elevator operations in line with safety protocols, demonstrating their pivotal role in crisis situations.

In summation, the ongoing research journey to enhance elevator system efficiency in healthcare facilities stands on the precipice of transformative change. Through the harmonious integration of machine learning, advanced passenger

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identification techniques, and IoT-based disaster alarms, elevators are poised to become more efficient, secure, and responsive to the intricate requirements of healthcare environments. This amalgamation of advancements presents a promising trajectory for elevating vertical transportation within healthcare settings.

III. METHODOLOY

The problem's solution has broken down into four sections. Each section has its solution to the challenges that the related work addresses.

A) Display passenger count & average arrival time

a) Inside Passenger Detection

The camera (Pi cam) installed inside the elevator can detect objects using image processing techniques. A raspberry pi 4 board is used to demonstrate the elevator model with all features. OpenCV library is used to perform object detection which is an open-source library for image processing. TensorFlow Lite is used because it enables on-device machine learning to run models on devices. TensorFlow Lite gives high performance with hardware acceleration and model optimization. The output is displayed to an outside digital display kept outside the elevator premises.

Figure 1: Identified 3 passengers inside elevator

b) Average Arrival Time Calculation

Each floor has a display indicating the average arrival time along with the inside passenger count. To calculate the average arrival time the following equation can be used.

$$X = (|a| + b) / c$$

X = Average Arrival Time of the elevator a = Floor level difference
b = Distance between 2 floors c = Average lift speed

After parameter values identified the output will be displayed in the outside display. According to the physically made elevator structure, parameter values can be taken and execute through Raspberry Pi board.

B) Identifying patients in wheelchairs and crutches

This methodology delineates the process of identifying individuals using wheelchairs and crutches within elevator systems. Drawing from diverse sources including healthcare facilities and accessibility organizations, a dataset encompassing individuals with varying ages, genders, and disability types will be compiled. Rigorous ethical considerations will be adhered to, ensuring participant consent and privacy.

Following data collection, preprocessing techniques will be employed to standardize and cleanse the dataset. Normalization, outlier removal, and missing data handling will be applied, while contextual information such as time and location will be integrated. Subsequently, representative features capturing unique mobility characteristics, such as gait patterns and wheelchair movements, will be extracted.

Techniques like Principal Component Analysis (PCA) may be employed to reduce feature space dimensions. Machine learning algorithms, notably Support Vector Machines (SVMs) and Neural Networks, will be explored for classification. Ensemble methods will be assessed to potentially enhance classification accuracy. Metrics like accuracy, precision, recall, and F1-score will evaluate model performance, employing cross-validation to ensure robustness and mitigate overfitting. Ethical considerations, encompassing participant privacy, consent, and anonymization, will be meticulously upheld.

C) Detecting Doctors & Nurses

This section provides an overview of the process that was followed in the creation of a smart elevator system that was adapted specifically for the healthcare sector. The primary purpose of this research is to improve elevator efficiency and the overall experience of using the elevator by identifying medical workers, such as physicians and nurses, through a combination of image processing techniques and the incorporation of a voice control system. This will allow the elevator to communicate with its users more effectively.

The identification of medical professionals involves multiple stages, one of which is the extraction of features from images followed by analysis of those images. Using sophisticated image processing techniques, certain features such as the placement of stethoscopes and nursing badges as well as distinguishable facial characteristics are identified and extracted. These characteristics are used as distinguishing

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markers in the construction of one-of-a-kind profiles for each individual medical professional.

This model is trained on the extracted features to efficiently differentiate between medical professionals such as doctors and nurses, as well as other persons who work in healthcare settings. To achieve the highest possible level of accuracy in classification, the iterative training process includes both parameter adjustment and optimization.

To implement voice control in an elevator, you would need a microphone or microphones installed in the elevator, along with voice recognition software and hardware to interpret the user's commands. The software would need to be trained to recognize specific voice commands, such as "floor 5" or "open door," and respond accordingly. Additionally, privacy concerns must be considered when implementing voice control, as voice recordings may contain sensitive or personal information. Appropriate measures, such as anonymizing or deleting data after use, should be taken to protect user privacy.

Figure 2: Identified 3 passengers inside elevator

Figure 3: Identified 3 passengers inside elevator

IV. CONCLUSION

This paper has critically addressed these limitations inherent in contemporary elevator management systems. Through the proposal of an innovative framework that harmoniously amalgamates advanced algorithms and the Internet of Things (IoT), our approach seeks to revolutionize elevator systems. By seamlessly integrating efficiency, security, and emergency responsiveness, the envisioned transformation aspires to redefine passenger experiences and robustly address potential crisis scenarios, contributing to the evolution of elevator systems into more adaptive and intelligent entities.

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