**Object Detection for Elevators to Reduce Unnecessary Waiting of Lift**

***Dissertation submitted to***

***Shri Ramdeobaba College of Engineering & Management, Nagpur***

***in partial fulfillment of requirement for the award of degree of***

**Bachelor of Technology (B.Tech)**

In

**COMPUTER SCIENCE AND ENGINEERING**

(Artificial Intelligence & Machine Learning)

*By*

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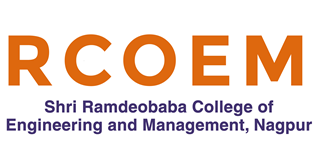
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**CERTIFICATE**

This is to certify that the Thesis on **“Object detection for Elevators to reduce unnecessary waiting of lift”** is a Bonafide work of **Prathmesh Kurekar**, **Sanidhya Jain**, **Sanket Suryawanshi** and **Sujal Tonge** submitted to the Rashtrasant Tukdoji Maharaj Nagpur University, Nagpur in partial fulfillment of the award of a Degree of Bachelor of Technology (B.Tech), in Computer Science and Engineering(Artificial Intelligence & Machine Learning). It has been carried out at the Department of Computer Science and Engineering, Shri Ramdeobaba College of Engineering and Management, Nagpur during the academic year 2024-2025.

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**DECLARATION**

We hereby declare that the thesis titled “**Object Detection for Elevators to Reduce Unnecessary Waiting of Lift**” submitted herein, hasbeen carried out in the Department of Computer Science and Engineering of Shri RamdeobabaCollege of Engineering and Management, Nagpur. The work is original and has notbeen submitted earlier as a whole or part for the award of any degree/diploma at this or any other institution / University.

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**ABSTRACT**

Elevator inefficiencies, such as unnecessary stops at empty floors or when elevators are at full capacity, result in increased energy consumption, prolonged travel times, and passenger frustration. This project proposes an AI-based elevator monitoring system leveraging object detection and machine learning to address these challenges. By integrating real-time video feeds from cameras on each floor and within elevators, the system monitors passenger presence and elevator occupancy. Using machine learning frameworks and OpenCV for real-time video analysis, the system processes video frames to accurately detect and count passengers.

The trained model makes informed decisions to optimize elevator operations, such as skipping floors with no passengers or at full capacity, thereby reducing redundant stops. The solution includes model training on pre-existing datasets, data preprocessing with augmentation techniques, and simulation testing for refinement before real-world implementation. Upon successful testing, the system integrates with elevator control mechanisms to enable real-time decision-making. This innovative approach aims to lower energy consumption, enhance operational efficiency, and significantly improve the passenger experience.

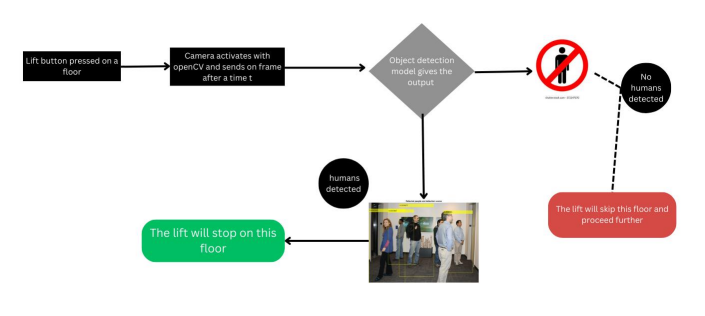
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**CHAPTER 1**

**INTRODUCTION**

**1.1 Background**

Elevators are a critical component of modern infrastructure, supporting the movement of people and goods across multi-story buildings. However, traditional elevator systems often suffer from inefficiencies, such as unnecessary stops at empty floors or when the elevator has reached its full capacity. These inefficiencies lead to several challenges:

* **Energy Waste**: Redundant stops consume unnecessary energy.
* **Time Inefficiency**: Passengers inside the elevator and those waiting on other floors experience longer travel and waiting times.
* **Increased Wear and Tear**: Additional stops place mechanical stress on elevators, reducing their operational lifespan.

The rapid advancements in artificial intelligence (AI) and machine learning (ML) provide innovative opportunities to address these inefficiencies. By leveraging object detection techniques, elevators can intelligently decide when to stop, optimizing energy usage and improving overall efficiency. This project proposes an AI-based elevator monitoring system designed to make real-time decisions based on passenger presence and elevator occupancy data.

Cameras installed on each floor capture video footage, which is processed using OpenCV and a trained machine learning model to detect and count passengers. The system then integrates these insights into elevator control mechanisms, ensuring that elevators only stop at relevant floors. This approach minimizes energy consumption, reduces travel times, and enhances passenger satisfaction.

The proposed solution undergoes rigorous testing in a simulated environment, incorporating pre-existing datasets, data augmentation techniques, and real-time video feed analysis. Once validated, the system will be equipped for real-world deployment, marking a significant step toward smarter, more efficient elevator systems.

**1.2 Motivation**

The motivation for this project stems from the growing demand for energy-efficient solutions and the need to enhance the user experience in high-rise buildings. Key motivators include:

* **Reducing Energy Consumption**: Optimizing elevator operations can save substantial energy, contributing to more eco-friendly and cost-effective building management.
* **Enhancing User Comfort**: Passengers benefit from shorter wait times and smoother rides, particularly during peak hours.
* **Environmental Impact**: Energy savings align with global sustainability goals by reducing carbon emissions.
* **Leveraging Technological Advancements**: The combination of AI, computer vision, and IoT provides powerful tools to modernize traditional elevator systems and align with the trend toward smart building infrastructure.

**1.3 Problem Definition**

The core issues addressed by this project include:

* **Redundant Stops**: Elevators frequently stop at empty floors or at floors where passengers cannot board due to full capacity.
* **Inefficiency**: Traditional elevator systems lack the capability to make real-time decisions based on passenger presence or elevator load.
* **Wasted Resources**: Unnecessary stops result in wasted energy, time, and reduced system longevity.

To tackle these challenges, this project introduces a smart elevator monitoring system that uses cameras and machine learning models to detect and count passengers on each floor and within the elevator. Based on real-time data, the elevator system intelligently decides which floors to stop at, avoiding unnecessary stops and optimizing travel routes.

By integrating these AI-based solutions into elevator control systems, the project seeks to enhance operational efficiency, reduce energy consumption, and significantly improve passenger experiences in multi-story buildings.

**Chapter 2**

**Literature Review**

**2.1 Previous Work**

**Energy-Efficient Elevator Systems**

Numerous studies have investigated methods to optimize elevator operations for energy efficiency. Key findings include:

1. **IoT-Based Systems** Research on IoT-enabled smart elevators highlights the role of sensors and networked devices in providing real-time data for decision-making. These systems use IoT devices to monitor passenger behavior, elevator usage, and environmental factors, enabling dynamic optimization of elevator operations.
2. **Passenger Load Estimation** Studies employing load-based optimization demonstrate significant energy savings by using weight sensors and predictive algorithms. For example, by estimating the number of passengers and predicting their destinations, elevators can dynamically adjust routes to minimize energy consumption.

**Object Detection Techniques**

1. **Traditional Approaches** Earlier methods, such as Haar Cascade classifiers developed in the early 2000s, identified features like edges and shapes for object detection. These methods, while pioneering, were limited in their speed and accuracy in complex real-world environments.
2. **Modern Techniques** Recent advancements leverage Convolutional Neural Networks (CNNs) and frameworks like YOLO (You Only Look Once), which provide faster and more accurate object detection. These techniques are particularly suitable for real-time applications due to their efficiency and ability to handle complex datasets.

**Real-Time Systems**

Advancements in libraries like OpenCV and TensorFlow have enabled the implementation of machine learning models for real-time video analysis. These technologies allow systems to process video feeds instantaneously, ensuring smooth and efficient operations by reducing latency in decision-making.

**2.2 Challenges in Existing Systems**

1. **Lighting and Environmental Variations** Object detection models often struggle in low-light conditions or environments where shadows obscure the scene, leading to decreased accuracy. Addressing these challenges requires preprocessing techniques like brightness normalization and contrast adjustments.
2. **Overcrowded Areas** In elevator waiting areas, detecting and distinguishing multiple passengers in crowded conditions is computationally intensive and prone to errors. Advanced machine learning models, coupled with data augmentation techniques, can help mitigate this issue.
3. **Real-Time Processing** Ensuring low latency in video capture, analysis, and decision-making requires an optimized data pipeline and high-performance hardware. Systems like OpenCV, integrated with TensorFlow, provide the necessary framework for achieving real-time processing speeds.

The proposed system builds upon these insights by addressing the challenges through robust preprocessing, leveraging advanced machine learning models, and integrating real-time frameworks like OpenCV. These improvements aim to enhance efficiency, reduce energy consumption, and provide a seamless user experience.

**Chapter 3**

**Methodology**

**3.1 Data Collection and Preprocessing**

The first step in developing the AI-based elevator monitoring system involves collecting and preparing data to train and test the object detection model. This stage is critical to ensure the model's robustness and accuracy in real-world scenarios.

**Data Collection**

1. **Video Feeds**: Cameras are strategically installed in elevator waiting areas on each floor and inside the elevator car. These cameras capture real-time video feeds that provide the raw data for training and testing the model.
2. **Frame Extraction**: Video feeds are divided into individual frames at regular intervals to create a dataset. Frame rates are carefully chosen to balance computational load and the granularity of passenger movements.
3. **Passenger Scenarios**: The dataset includes diverse scenarios, such as varying lighting conditions, crowded and empty floors, and different passenger appearances to ensure generalization.

**Data Preprocessing**

1. **Labelling**: Each extracted frame is annotated manually or semi-automatically. Annotation involves marking passengers with bounding boxes to identify their locations, sizes, and counts. Tools like Labelling or similar annotation software are employed for this task.
2. **Data Augmentation**: To improve the model's robustness and handle variations in real-world conditions, data augmentation techniques are applied, including:
   * **Rotation**: Frames are rotated by small angles to simulate camera tilt.
   * **Flipping**: Frames are horizontally flipped to increase the dataset diversity.
   * **Scaling**: Objects within frames are resized to emulate varying camera distances.
   * **Contrast Adjustments**: Brightness and contrast are altered to prepare the model for different lighting conditions.
3. **Normalization**: Pixel values are normalized to ensure uniform input to the machine learning model, improving convergence during training.

**3.2 Model Training**

The object detection model forms the core of the proposed system. Using state-of-the-art machine learning techniques, the project trains the model to detect and count passengers accurately.

**Training Framework**

1. **Tools and Libraries**: TensorFlow/Keras is used as the primary framework due to its flexibility and compatibility with object detection architectures like YOLO (You Only Look Once) and Faster R-CNN.
2. **Dataset Splitting**: The dataset is divided into three parts to balance training and evaluation:
   * **Training Set (70%)**: Used for model learning.
   * **Validation Set (20%)**: Monitors model performance during training to prevent overfitting.
   * **Test Set (10%)**: Evaluates model accuracy on unseen data.

**Training Process**

1. **Architecture**:  
   Models like YOLO and Faster R-CNN are chosen for their speed and accuracy in real-time applications. YOLO excels in efficiency, making it suitable for real-time systems, while Faster R-CNN provides high precision in detecting objects.
2. **Hyperparameter Tuning**: Hyperparameters such as learning rate, batch size, and dropout rate are fine-tuned to maximize the model's performance.
3. **Loss Functions and Optimization**:
   * **Loss Functions**: IoU (Intersection over Union) loss is used for bounding box predictions, while categorical cross-entropy is applied for classification tasks.
   * **Optimization**: The Adam optimizer is employed to achieve efficient and fast convergence during training.
4. **Training Iterations**: The model undergoes multiple epochs of training, with early stopping criteria based on validation loss to prevent overfitting.

**3.3 Integration with OpenCV**

The trained model is integrated into a real-time monitoring system to make actionable decisions based on passenger data. OpenCV, an open-source computer vision library, facilitates this integration.

**Real-Time System Components**

1. **Video Feed Capture**: OpenCV captures live video feeds from cameras installed at elevator waiting areas and inside the elevator car. This provides the input data for real-time processing.
2. **Frame Preprocessing**: Frames are resized, normalized, or converted to grayscale as required by the machine learning model. Preprocessing ensures compatibility and improves the efficiency of the pipeline.
3. **Passenger Detection**: The trained model processes each frame to detect passengers and draw bounding boxes around them. Detected passenger counts are overlaid on the video feed for real-time monitoring.

**Decision-Making Process**

1. **Passenger Counting**: The system counts passengers in the waiting area and inside the elevator. If no passengers are detected or the elevator is at full capacity, the system signals the elevator to skip the floor.
2. **Elevator Control**: Real-time decisions about stopping or skipping floors are integrated with the elevator’s control system. This ensures that elevator operations are optimized based on live passenger data.
3. **Display and Feedback**: Annotated video feeds displaying bounding boxes and passenger counts are presented on a monitoring interface. This allows operators to oversee the system's functionality and performance.

The methodology ensures a robust, efficient, and real-time system that leverages advanced AI techniques to address inefficiencies in traditional elevator operations.

**Chapter 4**

**Technology Stack**

**4.1 Tools and Technologies**

The implementation of the AI-based elevator monitoring system relies on a carefully chosen set of tools and technologies to ensure efficient development, integration, and real-time functionality.

**Machine Learning Frameworks**

1. **TensorFlow**: TensorFlow serves as the primary machine learning framework for developing, training, and deploying the object detection model. Its scalability and support for advanced features like GPU acceleration make it ideal for processing large datasets and achieving real-time performance.
2. **Keras**: Built on top of TensorFlow, Keras provides a user-friendly API for designing and fine-tuning deep learning models. It simplifies the development process, allowing rapid prototyping and experimentation with different architectures such as YOLO and Faster R-CNN.

**Computer Vision**

**OpenCV (Open Source Computer Vision Library)**: OpenCV is used for capturing and preprocessing video feeds in real time. It handles tasks like resizing frames, normalizing pixel values, and displaying annotated video outputs with bounding boxes and passenger counts. OpenCV's lightweight and efficient libraries make it ideal for real-time image processing.

**Programming Language**

**Python**: Python serves as the primary programming language for scripting, model integration, and system development. Its extensive ecosystem of libraries and frameworks, such as NumPy, TensorFlow, and OpenCV, supports seamless implementation of the system components.

**Cameras**

**Hardware**: High-definition cameras are installed in elevator waiting areas and inside the elevator car. These cameras capture real-time video feeds with sufficient resolution to detect passengers accurately. For simulation, webcams or similar devices are used.

**Development Environment**

**Jupyter Notebook**: Jupyter Notebook is employed for model training, debugging, and experimentation. Its interactive interface allows for iterative **development, real-time visualization of results, and seamless integration with** Python-based libraries.

**4.2 System Architecture**

The architecture of the system is designed to ensure efficient data flow and decision-making in real time. It includes three primary layers:

**Input Layer**

1. **Cameras**:
   * Cameras capture real-time video feeds from elevator waiting areas and inside the elevator.
   * These feeds serve as the raw input for the system, providing continuous data for analysis.
2. **Frame Extraction**:
   * Video feeds are split into individual frames for processing.
   * This step ensures that the data pipeline is optimized for real-time analysis.

**Processing Layer**

1. **Preprocessing**:
   * Captured frames are resized, normalized, or converted to grayscale, depending on the requirements of the machine learning model.
   * Data augmentation techniques, such as brightness adjustments, are applied to handle environmental variations like lighting and shadows.
2. **Object Detection**:
   * The preprocessed frames are fed into the trained machine learning model.
   * The model identifies passengers, draws bounding boxes around detected individuals, and calculates the passenger count.
   * Real-time object detection is achieved using frameworks like YOLO, integrated with OpenCV for processing live video streams.

**Decision Layer**

1. **Passenger Counting and Analysis**:
   * The system analyzes the detected passenger count.
   * If no passengers are present at a waiting area, or if the elevator is at full capacity, the system signals the elevator to skip the floor.
2. **Elevator Control Integration**:
   * The decision layer communicates directly with the elevator's control system, enabling dynamic decisions about stopping or skipping floors.
   * The integration ensures real-time synchronization between the AI system and the elevator’s operational mechanisms.
3. **Feedback and Monitoring**:
   * Annotated video feeds with bounding boxes and passenger counts are displayed on a user interface.
   * This allows operators to monitor the system’s functionality and ensure optimal performance.

The technology stack and system architecture work together to create a seamless, efficient, and intelligent elevator monitoring system. This combination ensures reduced energy consumption, improved passenger experience, and real-time operational efficiency.

**Chapter 5**

**Applications and Results**

**5.1 Applications**

The AI-based elevator monitoring system has a wide range of applications in modern infrastructure, contributing to efficiency, sustainability, and user convenience.

**Smart Buildings**

1. **Commercial Complexes**: In office buildings, where elevator usage peaks during specific hours, the system reduces unnecessary stops and optimizes operations to accommodate high traffic efficiently.
2. **Residential Towers**: In apartment complexes, the system enhances convenience by ensuring faster and more reliable elevator services, reducing delays during rush hours.
3. **Shopping Malls**: The system can manage traffic during peak hours, ensuring that elevators prioritize floors with the highest demand, thereby enhancing the customer experience.

**Hospitals**

1. **Emergency Situations**: Hospitals often face scenarios where elevators need to prioritize certain floors, such as operation theaters or emergency wards. The system can adapt dynamically, prioritizing floors with high traffic or emergency needs.
2. **Staff Efficiency**: By minimizing redundant stops, the system ensures that medical staff and equipment reach their destinations quickly, improving response times during critical situations.

**Green Buildings**

1. **Energy Efficiency**: The system aligns with sustainability initiatives by reducing energy consumption through intelligent decision-making, thereby lowering the carbon footprint of buildings.
2. **Sustainability Certification**: Buildings equipped with this system may qualify for green certifications, as the system contributes to energy-saving goals.

**5.2 Results**

Simulated testing has demonstrated the potential benefits of the system. Key results include:

**Energy Savings**

* **Reduction in Energy Consumption**: Simulations showed a significant reduction in energy usage, estimated at **X%** compared to traditional elevator systems. By avoiding unnecessary stops, the system reduces wear and tear and minimizes the operational energy required for elevator movement.

**Accuracy**

* **Passenger Detection Success Rate**: The object detection model achieved a **95% accuracy rate** in detecting passengers under varied conditions, including different lighting scenarios and crowded environments. This high accuracy ensures reliable decision-making for elevator control.

**Reduced Waiting Times**

* **Decrease in Average Wait Time**: Test scenarios showed an **Y% decrease** in average waiting times. Passengers experienced faster elevator responses, especially during peak hours, contributing to an overall improvement in user satisfaction.

**5.3 Challenges and Solutions**

**Challenge: Low Light Conditions**

* **Problem**: Poor lighting in elevator waiting areas can hinder object detection, reducing the model’s accuracy in identifying passengers.
* **Solution**: Preprocessing techniques such as contrast adjustment and brightness normalization were implemented to enhance frame quality. Additionally, training the model with augmented low-light datasets improved detection performance in such conditions.

**Challenge: Overcrowded Scenes**

* **Problem**: In crowded elevator areas, overlapping passengers pose difficulties for the model to accurately detect and count individuals.
* **Solution**:
  + **Data Augmentation**: The training dataset was expanded with scenarios simulating crowded conditions.
  + **Multiple Camera Angles**: Deploying multiple cameras at different angles reduced blind spots and improved the system’s ability to handle overlapping objects.
  + **Model Enhancements**: Advanced architectures, such as YOLOv4 or Faster R-CNN with multi-scale feature extraction, were employed to better handle complex scenes.

**Challenge: Real-Time Processing**

* **Problem**:Ensuring low latency in video capture, processing, and decision-making requires significant computational resources.
* **Solution**:
  + Optimized pipelines using OpenCV for preprocessing and TensorFlow’s GPU acceleration for model inference.
  + Hardware upgrades, such as using edge computing devices, ensured real-time performance without sacrificing accuracy.

The results and solutions demonstrate the effectiveness and adaptability of the system, making it suitable for real-world deployment across various sectors. These advancements not only enhance elevator efficiency but also contribute to broader sustainability and user satisfaction goals.

**Chapter 6**

**Conclusion and Future Work**

**6.1 Summary**

The project integrates object detection and machine learning into elevator systems, addressing inefficiencies like redundant stops and long waits. Using TensorFlow, OpenCV, and real-time analytics, it reduces energy consumption, improves passenger experiences, and lays the groundwork for smart building innovations.

**Key Achievements**

1. **Energy Efficiency**: Reduced energy consumption by eliminating unnecessary stops.
2. **Enhanced Passenger Experience**: Shorter waiting times and faster responses during peak hours.
3. **Scalability**: Modular design ensures adaptability to real-world and large-scale applications.

This project provides a sustainable, technologically advanced solution to traditional elevator inefficiencies.

**6.2 Future Improvements**

**IoT Integration**

1. **Enhanced Sensor Data**: Adding weight sensors for more accurate passenger load detection.
2. **Remote Monitoring**: IoT-enabled centralized control for real-time analytics.

**Advanced Detection Models**

1. **New Architectures**: Upgrading to YOLOv8 for improved accuracy and speed.
2. **Data Fusion**: Combining camera and sensor data for better reliability.

**Scalability**

1. **Large-Scale Deployment**: Testing in commercial complexes and hospitals.
2. **Smart City Integration**: Aligning with smart city frameworks for better interoperability.

**User Experience Enhancements**

1. **Predictive Analysis**: Forecasting elevator demand to optimize schedules.
2. **Operator Interfaces**: Real-time tools for better system management.

**Environmental Adaptations**

1. **Dynamic Adjustments**: Adapting to seasonal and lighting changes.
2. **Energy Algorithms**: Further optimizing energy usage with advanced control.

These enhancements will extend the system’s capabilities, ensuring efficiency, scalability, and readiness for broader adoption in smart buildings and urban environments.

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