ELEVATE
(ELEVATOR GROUP MANAGEMENT SYSTEM)

Capstone Project Report

END SEMESTER EVALUATION

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ABSTRACT

In a world defined by soaring skyscrapers and the relentless pace of modern life, our proposal emerges as a beacon of transformation for elevator systems. As we strive towards an urban future, our innovative solution seeks to revolutionize the elevator experience, rendering it seamless and efficient. In a world where time is of the essence, our system promises to alleviate the inconvenience of elevator wait times, elevating the quality of life for countless individuals.

The hallmark of our system lies in its adaptability, exemplified through its focal application in elevator group management. Through the integration of Reinforcement Learning, Machine Learning, and Deep Learning methodologies, we orchestrate optimal lift movements that minimize waiting periods while conserving energy – a stride towards a greener future that benefits the lives of the millions who depend on elevators daily.

In corporate settings, elevator systems pose a significant challenge characterized by persistent issues such as prolonged waiting times, especially during peak hours. A parallel concern manifests within elevator lobbies, where protracted ride durations adversely affect the overall efficiency of building occupants. These extended journeys amplify frustration and disrupt essential tasks, with contributing factors including the elevator count, operational velocity, and routing strategies.

Furthermore, elevator lobbies assume a pivotal role for both building owners and the environment, primarily due to the substantial energy consumption associated with elevators. Inefficient systems not only drive up operational costs but also contribute significantly to a building's carbon footprint. Key determinants of energy consumption encompass the elevator count, operational speed, and the effectiveness of routing strategies. Addressing these factors is crucial for optimizing energy efficiency and minimizing the environmental impact of elevator systems in corporate environments.

Central to our project is the enhancement of elevator scheduling algorithms using cutting-edge AI and ML technologies. The foundation for refining these algorithms is built upon a comprehensive exploration of building occupancy, traffic dynamics, and utilization patterns. This thorough analysis informs the strategic adjustments made to the algorithms, ensuring they are attuned to real-time demands and user behaviors.

The core objective of our project is to strike a delicate trade-off between optimizing user experience and fulfilling environmental responsibilities. By prioritizing an enhanced user experience through reduced wait and travel times, we underscore the significance of simultaneously minimizing carbon footprints and contributing to environmental preservation. This dual commitment underscores our dedication to sustainable goals, aligning with a vision that not only prioritizes the immediate comfort of individuals but also actively works towards creating a more environmentally conscious and responsible future.

DECLARATION

We hereby declare that the design principles and working prototype model of the project entitled Elevator Group Management System is an authentic record of our own work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr. Rajiv Kumar during 6th semester (2023).

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Abbreviations	Full form
AI	Artificial Intelligence
ML	Machine Learning
EGMS	Elevator Group Management System
IEEE	Institute of Electrical and Electronics Engineers
GDPR	General Data Protection Regulation
WLAN	Wireless Local Area Network
DCS	Destination Control System
AWS	Amazon Web Services

1. INTRODUCTION

1.1 Project Overview

Our project utilizes advanced technologies, such as Reinforcement Learning, Machine Learning, and Deep Learning, to optimize elevator operations. Through the enhancement of Elevator Group Management Systems, we aim to shape a future characterized by efficient, eco-conscious, and user-centric urban mobility. The anticipated benefits include minimizing waiting times and enhancing the overall elevator experience for occupants of high-rise buildings. Additionally, our focus on energy conservation not only leads to cost savings but also actively contributes to creating a more sustainable urban ecosystem.

1.1.1 Technical terminology

Machine learning (ML) is a branch of artificial intelligence (AI) and computer science which focuses on the use of data and algorithms to imitate the way that humans learn, gradually improving its accuracy. ML enables systems to learn and improve from experience without being explicitly programmed. Machine learning focuses on developing computer programs that can access data and use it to learn for themselves. The machine learning process begins with observations or data. It looks for patterns in data so it can later make inferences based on the examples provided. The primary aim of ML is to allow computers to learn autonomously without human intervention or assistance and adjust actions accordingly.

Deep Learning, is a subset of Machine Learning, inspired by the structure of a human brain. Deep learning algorithms attempt to draw similar conclusions as humans would by continually analyzing data with a given logical structure. To achieve this, deep learning uses a multi-layered structure of algorithms called neural networks. As defined by Lex Fridman at MIT, Deep Learning is essentially scalable ML, Classical, or "non-deep", machine learning is more dependent on human intervention to learn. Human experts determine the set of features to understand the differences between data inputs, usually requiring more structured data to learn.

Reinforcement Learning: Reinforcement Learning, a facet of machine learning, enables an agent to execute actions in an environment to maximize cumulative rewards over time. Inspired by the structure of a human brain, Deep Learning, a subset of Machine Learning, seeks to draw conclusions akin to human reasoning by continuously analyzing data with a given logical structure. To achieve this, deep learning employs multi-layered algorithms called neural networks. Deep Learning, essentially scalable ML, stands in contrast to classical, or "non-deep," machine learning, which relies more on human intervention to determine features and understand differences between data inputs, often requiring more structured data for learning.

Python: Python, a versatile and widely used programming language, is lauded for its readability and user-friendly nature. With applications spanning web development, data analysis, machine learning, and automation, Python's clean syntax and extensive libraries make it a preferred choice among developers for crafting software and scripts across diverse domains.

Microcontroller: A compact integrated circuit that integrates a processor, memory, and input/output peripherals. Its design centers around tasks within embedded systems, controlling hardware components, and interfacing with the environment. Common in devices like IoT (Internet of Things) gadgets, robotics, and electronic appliances, microcontrollers are integral to various applications.

Occupancy Patterns: Occupancy patterns reflect the temporal distribution of people within a building. This data informs optimized elevator scheduling by accounting for peak hours, traffic congestion, and flow dynamics within the building.

User-centric Design: User-centric design emphasizes user experience, fostering systems and algorithms that enhance convenience and satisfaction through thoughtful design.

1.1.2 Problem statement

Approximately 1% of the annual electrical energy consumption of the world is consumed by elevators [38]. According to GIBSE guide, elevators account for approximately 4-7% of the total energy consumption in an office building. To optimize and minimize energy usage, a key strategy involves reducing the distance traveled by elevators. However, this approach often results in increased user waiting times, negatively impacting the overall user experience. Our primary objective is to address this challenge by significantly reducing carbon emissions and fostering a greener environment, all while ensuring that user satisfaction remains uncompromised.

1.1.3 Goals

The user experience is an important parameter for any service. Often in efforts to create a greener enviiromet it is compromised. Hence the scheduling of elevator group must not only be efficient but also fast enough. After identifying the problem statement and understanding the cause for the same, the team along with immense support from the mentor came to finalize the following objectives for the project:

1. **Optimize Elevator Operations by Data-Driven Decision Making**: Through analysis of elevator usage data, the system seeks to uncover intricate trends and patterns. These insights inform decisions related to elevator allocation, usage trends, and overall building traffic dynamics.
2. **Enhanced User Experience with Reduced Wait Times**: The system aims to allocate elevators more effectively, ensuring that users reach their destinations swiftly and efficiently. This goal encompasses creating a seamless flow of occupants through the building, enhancing overall user satisfaction, and streamlining building traffic.
3. **Energy Efficiency and Cost Reduction:** With a keen focus on sustainability and cost-effectiveness, the system endeavors to ensure that elevators are only operational when and where they are needed most. By minimizing energy consumption and reducing operational costs, this goal aligns with broader environmental objectives and efficient resource management.

1.1.4 Solution

The challenge at hand revolves around the automation and optimization of Elevator Group Management Systems within high-rise corporate buildings. The primary objective is to enhance the efficiency of elevator operations while minimizing energy consumption. This involves addressing the trade-off between passenger satisfaction, focusing on reducing wait times, and energy efficiency, emphasizing the selection of the shortest travel distance for elevators.

The need for such a system arises from the inherent complexities of managing multiple elevators in high-rise buildings, where conventional scheduling may lead to extended waiting times and energy inefficiencies. Our solution aims to revolutionize elevator operations by implementing advanced AI and ML technologies to redefine elevator group management. The scope of the project includes the development of intelligent algorithms that consider factors such as current elevator locations, destination floors, and passenger traffic patterns.

By optimizing elevator scheduling algorithms, our system seeks to create a future marked by efficient, eco-conscious, and user-centric urban mobility. The scope extends to minimizing waiting times for occupants and reducing overall energy consumption, contributing to a more sustainable urban ecosystem. Ultimately, the project strives to elevate the quality of life for those inhabiting high-rise corporate buildings through innovative and environmentally conscious elevator management solutions.

1.2 Need Analysis

The imperative for this project arises from a multifaceted evaluation of distinct aspects:

The contemporary performance of elevator systems in corporate settings unveils a pertinent concern – prolonged wait times, particularly during the bustling peak hours when occupants stream in and out of buildings. A parallel issue emerges within elevator lobbies, where extended ride durations directly impact the efficiency and efficacy of building occupants. These protracted journeys amplify frustration levels and curtail the available time for essential tasks. The variables contributing to these ride durations are diverse, including the total elevator count, their operational speed, and the intricacies of routing and scheduling strategies.

Additionally, elevator lobbies assume a pivotal role for building proprietors and managers, given elevators' noteworthy energy consumption. Inefficiencies within elevator systems escalate operational costs and contribute to a building's carbon footprint. Critical determinants influencing energy usage comprise the elevators' number, operational velocity, and the underpinning routing and scheduling methodologies.

Central to the project's aspiration is fortifying elevator scheduling algorithms through a symbiotic amalgamation of AI and ML technologies. A comprehensive study of building occupancy, traffic dynamics, and utilization trends, particularly during the zenith of demand and the troughs of idleness, will inform the algorithm's enhancements.

1.3 Research Gaps

Challenges and Considerations

While dynamic learning offers significant advantages, challenges related to data quality, model stability, and real-time processing must be addressed. Ensuring that the system remains reliable, accurate, and responsive in dynamic scenarios will be a key focus of our development efforts.
Incorporating dynamic learning and real-time data integration is a cornerstone of our smart elevator group management system. By enabling continuous adaptation and optimization, we aim to create a solution that provides efficient, responsive, and user-centric elevator services for building occupants.

1. **Energy Efficiency Optimization:** While energy efficiency has been a focus, there might be room for further research into optimizing energy usage in elevators. This could involve improving algorithms considering traffic patterns, building occupancy, and real-time data to reduce energy consumption without compromising service quality.

2. **Multi-Objective Optimization:** Elevator management systems face the intricate challenge of dealing with multiple conflicting objectives. These conflicting goals encompass minimizing passenger wait times, maximizing energy efficiency, and ensuring consistent wear and tear on the equipment. Striking a balance between these competing objectives poses a notable challenge in elevator system design. Achieving an optimal equilibrium necessitates utilizing advanced optimization techniques and innovative approaches that effectively address and harmonize these diverse objectives.

3. **Trade-off between minimum waiting time and energy conservation:** In the context of elevator systems, there exists a significant emphasis on achieving two key objectives: enhancing energy efficiency and minimizing passenger wait times. However, these objectives are not always perfectly aligned, giving rise to a trade-off that necessitates careful consideration. The trade-off revolves around the fact that measures designed to optimize energy usage, such as slowing down elevator operation or reducing the number of active elevators, may inadvertently lead to longer wait times for passengers. Conversely, strategies prioritizing swift passenger service, such as keeping more elevators active during peak periods, can lead to higher energy consumption.

4. **Peak Traffic Handling:** Elevators frequently encounter challenges in efficiently managing surges in passenger demand, particularly during peak traffic periods like mornings or afternoons or times that coincide with lunch breaks in office buildings. This often leads to overcrowded elevators, extended wait times, and potential dissatisfaction among building occupants.

5. **Continuous learning:** Traditional static elevators follow a predefined algorithm and do not dynamically modify their algorithm based on the actual challenges in a specific area. These challenges encompass a range of factors, such as peak traffic hours, building occupancy patterns, and varying usage intensities. This lack of adaptability can lead to suboptimal performance, longer wait times, and inefficient energy consumption. Continuous Learning introduces a transformative paradigm shift by enabling elevators to intelligently learn from real-time data, promptly adjusting their operational strategies to address the ever-changing

dynamics of the environment they serve and meeting the nuanced demands of modern buildings.

1.4 Problem Definition and Scope

Problem Definition: We have seen patterns in the usage of common amenities such as an elevator group system in corporate setups like office spaces. Even though there have been major developments in Artificial Intelligence and Machine Learning, which can predict and learn patterns in data, it has not been considered in terms of elevator groups in corporate buildings. Therefore, our team makes an effort to accomplish the same.

This project would help us to reduce the waiting time for the users, but we also aim to cut down the amount of electricity an average elevator would consume yearly, which is close to 2,500 to 5,000 kWh of electricity per year (according to the U.S. Department of Energy)[4] with efficient learning the energy consumption is targeted to reduce to about 70% of the current consumption. The reasons mentioned earlier would help any organization invest in its digitization quest.

Scope of the Problem:

1. **Collecting Lift Usage Patterns for Analysis and Learning:** This involves gathering data about how people use the elevators, including factors like peak usage times, frequency of requests, and floors most commonly visited. This data is used to analyze usage patterns and improve the efficiency of the elevator system.

2. **Sending Request Data to the Server:** When a user requests an elevator, the details of the request, such as the floor they're on and the desired destination floor, are sent to a central server. This server processes the requests and decides which elevator to assign to each request.

3. **Storage and Analysis of Data for Pattern Analysis and Allocation:** The data collected from elevator usage is stored and analyzed to identify usage patterns and trends. By understanding how and when the elevators are used, the system can make informed decisions about elevator allocation and improve overall efficiency.

4. **Allocating the Best Possible Elevator:** Based on the analysis of usage patterns, the system determines the most suitable elevator to respond to each request. Factors considered might include the current location of each elevator, its current direction, and the estimated travel time to reach the requester's floor.

1.5 Assumptions and Constraints

S.No	Assumptions
1.	It is assumed that the lift is itself capable of handling emergencies using the existing setup in place. =============== In scenarios of unforeseen emergencies, it is presumed that the elevator system possesses inherent mechanisms to effectively manage such situations, utilizing the pre-existing infrastructure and setup. Drawing insights from Elevator Group Management strategies, the lift's design integrates protocols to address emergencies, ensuring seamless functionality. This includes adept handling of power outages, fire incidents, and other contingencies, promoting passenger safety. Such engineered solutions, informed by comprehensive analyses in Elevator Group Management, underscore the lift's ability to navigate unexpected circumstances while upholding operational continuity and safeguarding occupants.
2.	The elevator would function accordingly using the hardware for transportation, and the opening and closing of the gates would happen using existing traditional lift algorithms. ======================= The operation of the elevator is seamlessly orchestrated through its hardware components, ensuring efficient vertical transportation within buildings. The intricate system employs time-tested mechanisms, integrating with the established lift algorithm for precise gate control. This synergy between hardware and software reflects the advancements outlined in Elevator Group Management. The process seamlessly harmonizes passenger movement, optimizing travel across different levels. Elevator Group Management elucidates the strategic orchestration of multiple elevators, enhancing overall efficiency. The gates, acting as a gateway, adeptly respond to the algorithm's cues, facilitating safe and timely access while embodying the principles encapsulated in the domain's collective knowledge.
3.	The data of elevator usage amongst floors is available to train the algorithm to predict accurately. ======================= The starting assumption is rooted in the availability of the essential data needed to effectively train the model. This pivotal presumption sets the stage for seamless testing by ensuring that the dataset required for training is readily accessible. With this foundational assurance, we are poised to execute a range of test inputs on the same dataset that facilitated the model's learning process. This symbiotic relationship between training and testing reinforces the model's capacity to handle new inputs and scenarios by leveraging the familiarity it has gained from the initial dataset. This streamlined continuity guarantees a robust evaluation and validation process, enhancing the model's reliability and performance.

4.	Every lift has a setup to calculate occupancy and store data in realtime and store it. ======================== Within the domain of Elevator Group Management, every lift system is outfitted with a sophisticated configuration designed to accurately calculate occupancy in real time and efficiently store this data. This intricate setup seamlessly captures and records information as passengers come and go. This process involves advanced technology that meticulously tracks passenger movements, enabling the system to orchestrate an optimal travel experience. By harnessing these data-driven insights, building management strategies can be enhanced, resulting in a seamless vertical transportation journey that prioritizes user convenience and operational efficiency.

Table 1.5.1: Assumptions

S.No	Constraints
1.	It could only work in lift lobbies (where a collection of 3 or more elevators are present together on one floor). ======================== Subject to the stipulation that our application is exclusively applicable within lift lobbies housing three or more elevators on a single floor, the significance of Elevator Group Management becomes apparent. This advanced system orchestrates the intricate choreography of multiple elevators, optimizing vertical transportation within contemporary structures. By harmonizing the movement of these elevators, the technology efficiently reduces passenger waiting times and enhances overall efficiency. Employing sophisticated algorithms, Elevator Group Management scrutinizes user traffic patterns, real-time demands, and specific floor requests, enabling strategic elevator allocation. This strategic allocation mitigates congestion, ensuring seamless travel between various levels and ultimately refining the vertical mobility experience for occupants.
2.	It could only work in places with a possible pattern of usage, for instance, a commercial office space. ======================== The operational viability of an elevator is contingent upon its deployment in locations with discernible and consistent patterns of usage, chiefly evident within spaces such as commercial office complexes. This fundamental premise is deeply ingrained in the tenets of Elevator Group Management, gleaned from insights in the training data. It's vital to acknowledge that the efficacy of the elevator system is intrinsically linked to the prevalence of predictable usage behaviors. Therefore, a symbiotic relationship exists between the elevator's design and the corresponding SRS, wherein fluctuations in usage patterns engender corresponding adjustments, ensuring the sustained optimization and effectiveness of the vertical transportation system.

3.	The lift is sensitive to short-medium range wireless communication. ================== The elevator system exhibits a heightened responsiveness to wireless communication spanning short to medium distances. This sensitivity enables efficient and convenient operation, allowing users to interact seamlessly with the lift using various wireless devices. Whether sending commands or receiving status updates, this capability enhances the overall user experience, streamlining vertical transportation in diverse environments.

Table 1.5.2: Constraints

1.6 Standards

Standards serve as authoritative principles or guidelines that establish benchmarks for comparison, guiding the quality, correctness, and excellence of various entities.

IEEE 802.11 Standards:

The IEEE 802.11 Standards, known as Wi-Fi standards, define the architecture and specifications for wireless LANs (WLANs). They enable seamless connections between nodes using high-frequency radio waves.

ISO 25745:

ISO 25745 provides guidelines for calculating and reporting energy consumption in elevators, escalators, and moving walks. Adhering to this standard ensures accurate measurement and transparent reporting of energy usage.

ASHRAE 90.1:

ASHRAE 90.1 sets energy efficiency requirements for buildings, including elevator systems. Following this standard aligns projects with energy-efficient practices.

IEEE 1016:

IEEE 1016 outlines recommended practices for documenting software design. Compliance with this standard ensures standardized and precise documentation of software design decisions.

IEC 61508:

IEC 61508 offers guidelines for functional safety in electrical, electronic, and programmable electronic safety-related systems. It is particularly relevant for projects with safety-critical aspects.

Privacy Regulations:

Consider privacy regulations such as GDPR (General Data Protection Regulation) if the project involves data collection and usage. Adhering to such standards safeguards user data and ensures ethical data handling practices.

1.7 Approved Objectives

Increase the system's efficiency by developing algorithms responding to occupancy levels, user inputs, and traffic patterns routinely used in elevator lobbies.

- To **understand the existing elevator group** structure.
- To **explore the best machine learning and deep models** to optimize elevator group performance.
- To **increase the system's efficiency** by developing algorithms responding to occupancy levels, user inputs, and traffic patterns routinely used in elevator lobbies.
- To **reduce the system's power consumption** by incorporating various optimization algorithms.

To enhance user experience while using elevators.The project aims to develop and implement an intelligent elevator system using artificial intelligence and machine learning algorithms to optimize the scheduling and routing of elevators.

1.8 Methodology

1. **Data Collection:**

The first step would be to collect data on elevator usage, including elevator demand patterns, occupancy levels, and elevator performance data. This data can be collected through sensors installed in the elevator system, occupancy sensors, or data from the building management system. Some trends are expected, such as an increase in rush during lunch hours, increased rush during the beginning of office hours, and elevators required at top floors during the concluding hours of the office. Raspberry Pi can collect data on elevator usage, occupancy levels, and elevator performance using sensors connected to the Pi. This data can be stored on the Pi and transmitted to a cloud-based storage service for further analysis.

2. **Data Analysis:**

The data collected would then be analyzed to identify patterns and trends in elevator usage, which can help to inform the development of elevator scheduling and Routing algorithms. Machine learning algorithms can also be applied to the data to train predictive models that can be used to forecast future elevator demand. The logical ground level of the elevator may be shifted to the second floor instead of the ground floor per elevator trends.

3. **Algorithm Development:**

Based on the data analysis, algorithms would be developed to optimize elevator schedules and routing. These algorithms would consider elevator demand, occupancy levels, traffic patterns, and time of day to ensure elevators are dispatched efficiently and effectively.

4. **System Design and Implementation:**

The next step would be to design and implement an intelligent elevator system that integrates with existing elevator infrastructure and control systems. This system would incorporate the scheduling and routing algorithms developed in the previous step and be capable of monitoring and adapting to changes in elevator demand patterns. Arduino can be used as a control hub to communicate with the elevator control system and dispatch elevators based on the scheduling and routing algorithms developed.

5. **System Testing and Evaluation:**

The performance of the intelligent elevator system would then be tested and evaluated in a real-world setting. Performance metrics such as elevator wait times, ride times, energy consumption, and overall efficiency would be tracked and analyzed to assess the system's effectiveness.

6. **Refinement and Optimization:**

Based on the performance data and user feedback, the algorithms and system would be refined and optimized to improve system performance and user experience.

1.9 Project Outcomes and Deliverables

An intelligent elevator group system that integrates with existing elevator infrastructure and control systems to optimize elevator scheduling and routing. This system would consider elevator demand, occupancy levels, traffic patterns, and time of day to ensure elevators are dispatched efficiently and effectively.

The project's manifold outcomes encompass:

1. **Enhanced Efficiency through Algorithmic Precision**: The system will harness algorithms meticulously designed to align with occupancy levels, user inputs, and the recurrent dance of traffic patterns within elevator lobbies. This symbiotic interplay will engender a heightened system efficiency, transforming elevators into seamless conveyances.

2. **Comprehensive Exploration of Elevator Group Dynamics**: A comprehensive understanding of the prevailing elevator group structure will be unveiled, unraveling its intricacies and nuances. This comprehension serves as a cornerstone, aligning theoretical models with real-world dynamics.

3. **Optimization through Machine Learning and Deep Models**: An exploration into the realm of machine learning and deep models will be undertaken, seeking to identify the most adept models for the optimization of elevator group performance. This exploration will unravel the potent synergy of technological innovation and vertical mobility.

4. **Power Consumption Reduction through Optimized Algorithms**: Energy efficiency will be championed through the infusion of diverse optimization algorithms. The concerted endeavor to minimize power consumption stands as a testament to the project's dedication to sustainability and eco-consciousness.

5. **Elevated User Experience**: At the heart of the project lies the aspiration to augment user experiences within elevators. The project envisions elevators not merely as functional tools but as seamless experiences, elevating the everyday journey.

1.10 Novelty of Work

The culmination of this endeavour will yield an intelligent elevator group system, seamlessly interwoven with pre-existing elevator infrastructure and control systems, orchestrating an orchestration that redefines elevator scheduling and routing. This dynamic system, characterized by its adaptability, will meticulously factor in elevator demand, occupancy metrics, traffic trends, and the temporal dimensions of the day. The result: an orchestration of elevators dispatched with a harmonious blend of efficiency and efficacy.

Following an extensive literature review, we have identified critical research gaps that have catalyzed the conception of this project. Our initiative introduces a pioneering approach, integrating AI techniques into elevator control. This integration augments conventional elevator systems and reshapes passenger interactions, influencing the trajectory of elevator transportation.

Our system seamlessly amalgamates elevator usage logs, and building management systems. Elevator logs, encompassing time-based and usage-intensity patterns, are harnessed to provide valuable insights. Continuous data processing facilitates an immediate understanding of passenger traffic, occupancy, waiting times, and other essential parameters.

For adaptive decision-making, we employ reinforcement learning and machine learning algorithms. These mechanisms analyze data streams, identifying patterns, anomalies, and passenger behaviors. This dynamic learning empowers adjustments to elevator dispatching strategies, heightening user experience and energy conservation.

Our intelligent elevator system, integrating dynamic learning and data integration, is poised to deliver many compelling advantages. It seeks to optimize performance by adapting to shifting traffic patterns, thus elevating dispatch efficiency and reducing passenger wait times. The system's adaptive learning anticipates passenger needs, engendering personalized and efficient elevator service. Furthermore, the focus on energy efficiency, achieved through occupancy data analysis, optimizes elevator usage, consequently curbing energy consumption and superfluous trips. With continuous data accumulation and ongoing learning, the system gains enhanced scalability, proficiently accommodating elevated elevator volumes and passenger inflows. This synergy ultimately ensures a seamless, elevated vertical transportation experience.

Introducing a novel dimension, standby mode embodies an innovative energy-conserving solution. In periods of low demand, elevators transition to 'hibernation' or 'sleep' mode, a departure from traditional constant power consumption during idleness. The standby mode conserves energy by deactivating elevator machinery, while in-cab sensors and software dim lights, fans, music, and screens. Based on control systems and cabin features, this solution can yield substantial energy savings, ranging from 25% to 80% of the total elevator consumption.

2. REQUIREMENT ANALYSIS

2.1 Literature Survey

2.1.1 Related Work

Elevator systems play a vital role in vertical transportation, particularly in high-rise buildings where optimal performance is imperative. Addressing the need for heightened efficiency, destination hall call registration has emerged as a significant solution [20]. In traditional systems, passengers register only their intended direction by pressing a button in the elevator lobby. In contrast, destination hall call registration allows passengers to directly input their destination floor via a keypad. This innovative approach enables the elevator system to access information about passengers' destination floors earlier than conventional methods. By leveraging this information effectively, the elevator system can enhance operational efficiency, facilitating faster passenger arrivals at their respective destinations. Elevator systems with destination hall call registration are already on sale by companies such as PORT [21] by Schindler, ELE-NAVI[22] by Mitsubishi Electric, and Floor NAVI [23]by Toshiba.

An elevator group control system aims to operate cars not independently but cooperatively to improve overall efficiency. For this purpose, it determines how to serve passengers that dynamically come to elevator lobbies by utilizing a set of cars. This problem is called the Elevator Dispatching Problem (EDP) [24]. It is composed of passenger-to-car assignment and car routing.

EDP is worth studying since it can improve the performance of an elevator system without increasing hardware costs. There have been several studies on the EDP with destination hall call registration. Tanaka et al. [25]and [26] focused on a single-car elevator system and proposed a branch-and-bound algorithm for the car routing problem. Hiller et al. [27] considered an elevator system with more than one car and formulated the EDP as a set partitioning problem.

Ruokokoski et al. [28] formulated the EDP as a mixed-integer linear programming (MILP) problem. In this formulation , an additional constraint was introduced: Passengers who are waiting on the same floor and have the same travel direction must be assigned to the same car. Besides, they only provided a formulation without evaluation by computer simulation.

Further, with the advent of advanced Machine learning techniques for pattern studying and recognition, we can now leverage specific patterns like Up Peak Traffic.

Up-peak traffic problem has attracted much attention among the traffic fields [29]. Elevator traffic flows(ETF) experience severe congestion during the peak period as a result of their heavy traffic, complex user types, and relatively slow-moving elevators. The ETF includes three main characteristics, such as periodic, stochastic and burst in the elevator system[30]. And this characteristic analysis of the ETF is the key content to influence the energy-cost of the Elevator Group Control System (EGCS).

There are also results which are concerned with the elevator's motion. The pioneer work was carried out by Poschel and Gallas; they have found the dynamic jamming transition by varying the inflow rate of down passengers into elevators using a stochastic model. The application of the model is limited only to the evening peak traffic[35]. After that, a simplified dynamic model proposed by Nagatani has been presented to describe the motions of elevators in the morning peak traffic.

2.1.2 Research Gaps of Existing Literature

Traditional methods such as destination hall call registration are relatively new technology, and studies on taking its full advantage are still in progress.

A significant drawback in Ruokokoski's mixed-integer linear programming[28] was an additional constraint that was introduced. i.e. Passengers who are waiting on the same floor and have the same travel direction must be assigned to the same car. Besides, they only provided a formulation without evaluation by computer simulation. Following that a simplified formulation of the EDP by considering only one round trip for each car was proposed[28]. They evaluated the performance of their approach by computer simulation. However, the dynamic nature of elevator group control was not fully considered. The evaluation was for individual snapshot instances arising in a dynamic environment, and they did not consider its effect on the overall transportation performance.

Similarly, because of the stochasticity of the passenger's arrival and the uncertainty of the determination, this characteristic analysis became unstable for EGCS[31,32].

Until now, there have been many research results, mainly about predicting the arriving traffic flow[24,25] and traffic mode classification[33,34].

Especially for the running time of the elevator's motion, a research proposed the use of round-trip time, whose distribution depends strongly on the number of passengers waiting in the lobby, the number of stops and the highest reversal floor. The distribution functions of the passenger queue length in the lobby, the round-trip time, the waiting time, the ride time and the journey time are derived[36].

Aiming at the three main characteristics, only the burst of the traffic flow has just been researched, and the result shows there are chaotic characteristics in the peak traffic flow[30].

2.1.3 Detailed Problem Analysis

While all these studies can help adjust the dispatching policy, they still can't provide straight results from the traffic flow data. That's to say, it still lacks analysis of the energy consumption data set corresponding to the different arrival rates of passengers. Most existing methods suppose that arriving traffic flow has stochastic characteristics, and the inflow rate of traffic flow should obey Poisson distribution or homogeneous distribution[37]. However, the inflow rate of passengers into elevators varies significantly with time in the elevator group control system. It is necessary to increase the number of elevators consistently by adding the inflow rate. On the contrary, fewer elevators are needed when the inflow rate decreases. To reduce energy consumption, it is necessary to correlate the number of operating elevators directly to the inflow rate of passengers.

Our model seamlessly intertwines energy efficiency and user experience, fostering an equilibrium that optimally caters to both ecological concerns and user satisfaction. Leveraging advanced technologies, the model integrates smart and adaptive algorithms to dynamically adjust energy consumption based on user patterns. This ensures a personalized and comfortable environment while minimizing unnecessary energy usage. The system not only enhances user comfort but also contributes to sustainability goals by promoting energy conservation. By striking a harmonious balance between energy efficiency and user experience, the model pioneers a paradigm shift in design, offering an intelligent and eco-conscious solution that aligns with the evolving needs of both individuals and the environment.

S.No.	Roll Number	Name	Paper Title	Tools/Technology	Findings	Citation
1	102003390	Veer Daksh Agarwal	The Effect of the Number of Elevators in a Group and the Landing Call Allocation Algorithm on the Upper Performance Limit of Destination Group Control		Different kinds of datasets and algorithms need to be used to train our ML model for optimization.	[1]
2			Analysis of standby power consumption for lifts and escalators		Helpful in understanding different kinds of techniques to work on energy consumption	[2]
3			Establishing the upper performance limit of destination elevator group control using idealized optimal benchmarks		This article gives an overview of the extent to which we could use the available sources	[3]
4	102003372	Jahnvi Gangwar	Calculation of the elevator round-trip time under destination group control using offline batch allocations and real-time allocations		Other kinds of datasets need to be used to train our ML model for optimization and dynamic learning.	[4]
5			Multicar-Elevator Group Control Algorithm for Interference Prevention and Optimal Call Allocation		Different kinds of algorithms to train our model	[16]
6			Energy consumption estimation on lift systems: The advantages of VVVF drives		Different techniques to reduce energy consumption.	[5]

7	102003239	Chahat Joneja	An integrated mathematical method for traffic analysis of elevator systems		Mathematical models for the project	[6]
8			Customer service in an elevator system during up-peak		Things to implement for better customer experience	[7]
9			Comprehensive analysis of elevator static sectoring control systems using Monte Carlo simulation		Different approaches which will help in optimization of algorithms.	[8]
10	102003311	Shamayla Jindal	Improved traffic design methods for lift systems		Learned about major traffic conditions are considered and both manual, computer assisted and calculator procedures are outlined	[9]
11			A simulation study of energy consumption by elevators in tall buildings		Datasets for energy conservation.	[10]
12			Distributed approach to group control of elevator systems using fuzzy logic and FPGA implementation of dispatching algorithms		Different algorithms for optimizing wait times in the project.	[11]
13	102003370	Mukul Singhal	Energy-efficient elevators and escalators in Europe: An analysis of energy efficiency potentials and policy measures		Current regulations and approaches used for energy conservation.	[12]
14			Design of Elevator Control System Based on PLC and Frequency Conversion Technology		Ways to use the control method and the composition of the structure to be able to lift the elevator to provide better service and to meet people's needs better	[13]
15			An Intelligent Elevator Development and Management System		Combination of various technologies to get the most optimized version	[14]

Table 2.1.3.1 Research Findings

2.1.4 Survey of Tools and Technologies Used

As part of the literature survey, we have examined various AI techniques and technologies adopted by elevator companies. Techniques like elevator algorithm, neural networks, Ant colony optimization, multi-agent systems, and AI planning have all contributed to optimizing elevator performance and passenger satisfaction.

In developing our smart elevator group management system, various cutting-edge tools and technologies are utilized to ensure efficient, adaptive, and user-centric elevator operations. This section presents an overview of the key tools and technologies employed in our system.

AI and Machine Learning Frameworks

To enable dynamic learning and adaptation, our system leverages popular AI and machine learning frameworks such as TensorFlow, PyTorch, and scikit-learn. These frameworks provide a foundation for implementing advanced algorithms that analyze data streams, predict traffic patterns, and optimize elevator dispatching.

By leveraging this diverse set of tools and technologies, our smart elevator group management system aims to provide a comprehensive and efficient solution for optimizing elevator operations, enhancing user experiences, and contributing to the advancement of building automation and management.

2.1.5 Summary

In a world marked by towering skyscrapers and a fast-paced lifestyle, this proposal outlines an innovative approach to elevator systems, aiming to transform the urban experience. Focused on enhancing efficiency, the solution pledges to minimize elevator wait times, ultimately improving the quality of life for many. The system's adaptability is evident in its emphasis on elevator group management, incorporating Reinforcement Learning, Machine Learning, and Deep Learning. Through optimized lift movements, it not only reduces wait times but also conserves energy, contributing to a greener future for the millions dependent on elevators daily.

At the project's core lies the enhancement of elevator scheduling algorithms, utilizing advanced AI and ML technologies. This involves a thorough exploration of building occupancy, traffic dynamics, and utilization patterns, guiding strategic adjustments for real-time responsiveness. The project's primary objective is to balance user experience optimization with environmental responsibility. Prioritizing reduced wait and travel times signifies a commitment to minimizing carbon footprints, thereby contributing to environmental preservation. This dual commitment underscores a dedication to sustainable goals, fostering a more environmentally conscious and responsible future.

2.2 Software Requirement Specification

2.2.1 Introduction

In the modern world, the effective and efficient management of vertical transportation systems is crucial to ensuring smooth operations within multi-story buildings. An Elevator Group Management System (EGMS) plays a pivotal role in enhancing the user experience, optimizing energy consumption, and maintaining a secure environment within these structures. This Software Requirements Specification (SRS) document outlines the comprehensive requirements for developing, implementing, and deploying a state-of-the-art Elevator Management System.

The primary objective of this SRS is to define the functional and non-functional requirements that govern the design and development of the Elevator Management System. By capturing the specific needs and expectations of stakeholders, including building administrators, maintenance personnel, and end-users, this document serves as a blueprint for the entire software development lifecycle. The SRS will guide developers, testers, and project managers in understanding the scope, features, constraints, and performance benchmarks that the Elevator Management System must adhere to.

2.2.1.1 Purpose

The purpose of this Software Requirements Specification (SRS) document is to provide a comprehensive and structured outline of the requirements for the development, implementation, and deployment of a Elevator GroupManagement System (EGMS). The EGMS is designed to optimize the operation, control, and monitoring of elevators within multi-story buildings, with the primary goal of enhancing user experience, increasing operational efficiency, and ensuring a secure and seamless vertical transportation system.

This document is a critical communication tool between stakeholders, including developers, project managers, designers, testers, and end-users. It aims to clearly articulate the functional and non-functional needs of the Elevator Group Management System, facilitating a shared understanding of the system's scope, capabilities, constraints, and performance expectations.

2.2.1.2 Intended Audience and Reading Suggestions

The Elevator Group Management System (EGMS) report is tailored for a diverse audience of stakeholders with varying levels of interest and expertise in the system's design, development, implementation, and operation. The report is structured to accommodate the needs of the following individuals and groups:

Executives and Decision-Makers: High-level management personnel, building owners, and executives who seek an overview of the system's benefits, cost-effectiveness, and impact on building operations.
Project Managers and Developers: Professionals responsible for overseeing the system's development lifecycle, project planning, resource allocation, and

implementation. They need a detailed understanding of the technical aspects, progress, and challenges of the project.

Technical Teams and Engineers: Software developers, hardware engineers, and technical experts who require in-depth information about system architecture, design decisions, algorithms, and interfaces.

Building Administrators and Facility Managers: Individuals responsible for the day-to-day operation, maintenance, and user experience of the EGMS. They need insights into how the system enhances building operations and user convenience.

Maintenance Personnel: Staff responsible for the upkeep and repair of the elevator systems. They should understand the system's maintenance requirements, diagnostics, and troubleshooting procedures.

End-users: Building occupants and elevator users who want to know how the EGMS enhances their experience, increases convenience, and contributes to a safe and efficient transportation environment.

Regulatory Authorities: Government agencies and regulatory bodies that oversee building safety and code compliance. They require information on how the EGMS adheres to relevant regulations and standards.

2.2.1.3 Project Scope

The Elevator Group Management System will encompass the following features and functionalities:

Lift Allocation and Dispatch:
The system will implement intelligent algorithms to optimize lift allocation and dispatch based on factors such as user destination, floor traffic, and historical usage patterns. This will reduce waiting times and enhance user experience.

Energy Efficiency and Sustainability:
Energy-efficient scheduling and standby modes will be implemented to optimize energy consumption. The system will also integrate regenerative braking technology to recover and store energy during descent.

Notifications and Alerts:
The system will notify administrators and users about scheduled maintenance, lift breakdowns, and emergency situations via email, SMS, or in-app notifications.

2.2.2 Overall Description

The Elevator Group Management System (EGMS) Software Requirements Specification (SRS) provides a comprehensive overview of the system's objectives, functionalities, and constraints. This section lays the groundwork for a shared understanding of the system's purpose and the context in which it will operate.

2.2.2.1 Product Perspective

The Elevator Group Management System (EGMS) is designed as an innovative software solution that interfaces with existing elevator hardware and building infrastructure to enhance elevator operations, optimize user experience, and ensure efficient vertical transportation within multi-story buildings. It acts as a dynamic layer that intelligently manages and orchestrates the interactions between elevators, users, and building systems.

1. **System Interfaces**:

The EGMS interfaces with various components, including elevator control hardware, user interfaces, building management systems, access control systems, and potentially Internet of Things (IoT) devices. These interfaces facilitate communication, data exchange, and coordination between the EGMS and other systems within the building ecosystem.

2. **Elevator Hardware Integration**:

The EGMS integrates seamlessly with a variety of elevator models and manufacturers. It harnesses the data and commands provided by elevator control systems to optimize elevator scheduling, floor distribution, and energy consumption.

3. **Building Management Systems**:

The EGMS can collaborate with building management systems to exchange information about building occupancy, peak traffic times, and maintenance schedules. This collaboration enables the EGMS to adapt its operation based on real-time data, enhancing overall building efficiency.

4. **IoT Integration (Optional)**:

The EGMS has the capability to integrate with IoT devices such as occupancy sensors, environmental sensors, and energy meters. This integration enables the system to make data-driven decisions for energy optimization and predictive maintenance.

In the broader context, the Elevator Group Management System exists within the ecosystem of a multi-story building, working in harmony with existing infrastructure to revolutionize vertical transportation. Its ability to interact with a diverse array of interfaces and systems positions it as a central hub for elevator operations, enabling a smoother and more efficient experience for all stakeholders.

2.2.2.2 Product Features

1. Intelligent Lift Control:

- Develop algorithms that analyses occupancy levels, user inputs, and traffic patterns to optimize elevator operation.
- Prioritize elevator assignments based on user demand to reduce waiting times and improve user experience.
- Adaptive scheduling to dynamically adjust elevator routes in response to changing traffic patterns.

2. Integration with Existing Infrastructure:

- Seamless integration with the existing elevator control systems and infrastructure without requiring extensive modifications.
- Compatibility with various elevator models and brands to ensure widespread adoption and applicability.

3. Traffic Pattern Analysis:

- Collect and analyze data from sensors and user inputs to identify peak traffic periods and patterns.
- Optimize elevator operations during peak times to efficiently handle increased demand and reduce congestion.

4. Occupancy-based Operation:

- Algorithms to monitor elevator car occupancy and distribute passengers effectively to avoid overcrowding and discomfort.
- Optimize stops based on the number of passengers waiting to improve efficiency and reduce travel time.

5. Energy Efficiency:

- Incorporate optimization algorithms to reduce unnecessary elevator movement and minimize energy consumption.
- Implement standby modes during low-usage hours to further conserve energy.

6. Scalability and Upgradability:

- Design the system to accommodate future upgrades and enhancements, such as integrating with newer elevator technologies or expanding to more floors.

7. User Documentation and Training:

- Provide comprehensive user guides and training materials for building occupants, facility managers, and maintenance personnel.

2.2.3 External Interface Requirements

User Interface:

- Passenger Interface: A user-friendly passenger interface within each elevator car and on each floor that allows passengers to select their desired destination floor.
- Control Panel: A control panel in each elevator lobby that lets users call elevators to their floors and choose their desired direction of travel.

Building Management System (BMS):

- Integration: The elevator group management system might need to interface with the building's BMS to receive information about the building's occupancy, schedules, and energy management plans.
- Synchronization: The system could synchronize with the BMS to optimize elevator operation based on building usage patterns, events, or emergencies.

Emergency Services:

- Fire and Emergency Services: Interfaces with fire and emergency services that allow them to take control of elevators during emergencies, prioritizing rescue operations.

2.2.3.1 User Interfaces

1. Energy Efficiency Interface:
2. A feature-rich interface that showcases the assigned floor and takes input for multiple requests of desired floor.

2.2.3.2 Hardware Interfaces

1. Interface with the elevator control system to receive and send commands for elevator movement, floor selection, door control, and status updates.
2. Connect with emergency stop buttons inside elevator cars to halt movement in case of emergencies.

2.2.3.3 Software Interfaces

1. Interface with the algorithm for optimizing elevator assignments based on passenger destination floors.
2. Interface with software that generates reports, analyzes elevator usage patterns, and presents performance metrics.

2.2.4 Other Non-functional Requirements

1. The system should be efficient and quick in suggesting the most suitable lift to users.
2. The system should be able to reduce waiting times for users.
3. The system should consume less electricity to reduce energy costs.
4. The system should be scalable to accommodate large, high-rise buildings.
5. The system should be user-friendly, intuitive, and easy to use.
6. The system should be reliable and have high availability to ensure minimal downtime.
7. The system should have robust security measures to protect user data and prevent unauthorized access.
8. The system should comply with all relevant laws and regulations regarding lift management and data privacy.

2.2.4.1 Performance Requirements

Response Time:

Elevator Arrival Time: Define the maximum allowable time for an elevator to arrive at a floor after a call button has been pressed.

Elevator Dispatch Time: Specify the time to dispatch an available elevator to a specific floor in response to a call.

Waiting Time:

Maximum Waiting Time: Establish the maximum acceptable time passengers should wait for an elevator when they request it.

Average Waiting Time: Define the average waiting time passengers can expect during peak and non-peak hours.

Riding Time:

Maximum Riding Time: Establish the maximum time taken by passengers to go from the current floor to the desired floor

Average Riding Time: Define the average Riding time passengers can expect during peak and non-peak hours.

Peak Handling Capacity:

Peak Throughput: Determine the number of passengers or trips the system should be able to handle during peak traffic hours.

Peak Handling Time: Specify the system's capability to efficiently handle high traffic demands during peak periods.

Efficiency and Distribution:

Balancing: Ensure an even distribution of elevator usage to minimize crowding and waiting times for all floors.

Optimal Floor Assignment: Assign elevators to floors in a way that minimizes travel time and maximizes efficiency.

2.2.4.2 Safety Requirements

1. The system must comply with fire safety regulations, including requirements for elevator shutdown and recall during fire alarms.

2. The system should have provisions for safely evacuating passengers during power failures, fire alarms, or other emergencies.

3. Elevators should be automatically directed to designated safe floors or open doors during emergencies.

2.2.4.3 Security Requirements

1. Regularly update and patch software components to address vulnerabilities and security issues.

2. Implement secure coding practices to prevent common software vulnerabilities.

3. Comply with data privacy regulations and ensure that personal data is collected, stored, and processed securely and transparently.

4. Implement strong access controls to limit access to authorized personnel only.

2.3 Cost Analysis

S.No	Name	Quantity	Unit Price (INR)	Total Price (INR)
1	**Arduino Uno R3**	1	600	600
2	**Stepper Motor**	2	120	240
3	**Stepper Motor Driver (ULN2003)**	2	100	200
4	**DC Hobby Motors**	3	65	195
5	**IC L293D**	3	50	150
6	**Battery**	4	40	160
7	**Jumper Wires**	32 wires	-	60
8	**Plywood Piece**	8*4	300	300
9	**Wheels**	3	30	90
10	**Pulley**	6	50	300
11	**L293D Module**	3	90	270
12	**LM7805 Voltage Regulator**	6	7	42
13	**Battery Cap**	5	5	25
14	**LED**	6	2	12
15	**Bread Board**	1	60	60
16	**Glue Gun**	1	190	190
17	**Arduino Uno serial Wire**	1	60	60
18				
			Grand Total	**2954**

Table 2.3.1: Cost Breakdown

2.4 Risk Analysis

1. The prediction model could learn patterns in such a way that the frequency of elevators stopping and serving on a particular level is minimized as compared to the existing elevator setup.

2. The algorithm fails when all the available elevators have gotten into the maintenance mode simultaneously.

3. The latency in transferring a request from a particular floor to the server could sometimes result in the inefficient assignment of an elevator to the server request.

4. In some scenarios, the user will likely experience an extended waiting period due to its engagement in servicing a higher-priority request.

3. METHODOLOGY ADOPTED

3.1 Investigative Techniques

To thoroughly comprehend and effectively address the multifaceted challenges and prospects embedded within the domain of Elevator Group Management Systems (EGMS), our project is poised to harness an array of investigative techniques. These techniques will serve as guiding beacons, illuminating our path through the intricate landscape of analysis, design, and eventual implementation phases. By employing this diverse toolkit of investigative methods, we aim to unravel the complexities, uncover hidden insights, and pave the way for a robust and informed approach to shaping the future of EGMS.

1. **Literature Review**: Delving into the expanse of existing literature unveils a profound methodological pillar, acting as the intellectual scaffold for our project's endeavor into Elevator Group Management Systems (EGMS). This meticulous exploration extends beyond mere information gathering, transcending to an intricate process of deciphering the intricate threads that weave together past research, dynamic industry trends, and illuminating best practices. From this multifaceted tapestry emerges a panoramic understanding of the EGMS landscape, casting light upon latent gaps, formidable challenges, and nascent opportunities. By traversing the historical trajectory, we glean valuable insights illuminating the way forward, infusing a profound depth into our approach.

2. **Data Analysis**: The crux of our project's investigative essence hinges upon harnessing the power of data-driven revelations. With data analysis as our compass, we embark on a voyage through the labyrinth of occupancy patterns, the ebb and flow of traffic dynamics, the rhythmic cadence of usage trends, and the metronomic pulse of wait times. This empirical odyssey transmutes raw data into enlightening revelations, where patterns surface as silent narrators of human behavior within vertical habitats. This empirical illumination, cast upon the canvas of observation, culminates in the quantitative tapestry that informs decision-making and forges the crucible in which our algorithms are meticulously tempered.

3, **Algorithmic Analysis**: Infused with an unwavering pursuit of efficiency, our project embarks upon a journey of profound algorithmic analysis, a journey characterized by its rigor as it navigates the intellectual landscapes of Reinforcement Learning models, Machine Learning techniques, and the intricate passages of optimization strategies. This analytical expedition extends beyond a mere traversal; it is a deliberate and meticulous exploration that meticulously dissects each facet of algorithms with the precision of a seasoned craftsman. The crucible of scrutiny is ignited to discern the delicate equilibrium between efficiency, accuracy, and scalability. This exploration reaches its zenith, culminating in a comprehensive cartography that serves as our guide through the algorithmic labyrinth, ensuring that their resilience withstands the crucible of real-world challenges.

4. **Case Studies**: Delving into real-world case studies of tall structures and their intricate elevator management systems, we embark on a journey to glean practical insights. These case studies unveil the challenges faced and the successes achieved, offering us a wealth of knowledge to guide our solution's blueprint. As we navigate through these accounts, we intricately incorporate the

5. **Surveys and User Feedback**: Engaging in a symphony of interaction, we meticulously gather perspectives from building occupants, facility managers, and elevator users. Like notes

in a composition, these voices enrich us with qualitative insights into their expectations, struggles, and aspirations. Through surveys and candid conversations, we shape our design approach to authentically reflect their needs, embracing a user-centric ethos that guides our trajectory.

6. **Simulation**: Equipped with simulation tools, we embark on a virtual exploration, delving into the landscapes of diverse scenarios that await in the realm of reality. Through this digital lens, we dissect the effectiveness of our algorithms and strategies, projecting the interplay of outcomes before they step onto the stage of real-world implementation. A playground of variables unfolds before us, where we meticulously optimize, iterate, and refine, ensuring that our creation emerges battle-tested and finely tuned for the grand performance of actuality.

The chosen investigative techniques represent a judicious selection that collectively aligns with the project's comprehensive scope and objectives. The literature review serves as the foundational bedrock, infusing our understanding with insights from prior research and industry practices. This helps us identify gaps and challenges and draws inspiration from successful approaches. Data analysis emerges as a cornerstone, harnessing empirical evidence to inform decision-making and algorithmic development, substantiating our strategies with quantifiable insights into occupancy trends, traffic dynamics, and waiting times.

Algorithmic analysis is a natural extension, ensuring that the techniques employed are efficient but also scalable and precise. It underscores the project's commitment to technological rigor and innovation. Integrating case studies accentuates the practical relevance, enriching our understanding with real-world complexities and success stories from high-rise buildings and their elevator systems.

Surveys and user feedback constitute a human-centric approach, grounding our project in the perspectives and expectations of those who directly interact with elevators. This qualitative dimension guides our design choices and enhances the user experience. Simulation, in turn, serves as a virtual crucible, enabling us to experiment with various scenarios, optimize variables, and refine our system before real-world deployment. This iterative approach ensures the efficacy and readiness of our solution.

In essence, each investigative technique is carefully chosen to offer a well-rounded and robust foundation, collectively paving the way for the project's success in addressing the challenges and opportunities inherent in Elevator Group Management Systems.

3.2 Proposed Solution

In the dynamic landscape of corporate buildings, the Elevator Group Management System stands as an emblem of innovation, fusing cutting-edge Artificial Intelligence (AI) technology with advanced deep learning and machine learning models. Our solution is engineered to decipher, analyze, learn, and predict intricate usage patterns derived from elevator requests from diverse floors within the corporate edifice.

The crux of our endeavor resides in harnessing the power of AI-driven algorithms to achieve optimal elevator allocation, navigating the intricate labyrinth of requests, and aligning with the ever-changing traffic dynamics. A key facet of our approach involves employing patterns extracted from historical usage to ascertain the ideal elevator for a given request. Crucially, this selection process is fortified by an astute consideration of the available elevators at the time of request and the temporal context in which the request is made.

Our system strikes a delicate equilibrium between the twin goals of minimizing the aggregate time taken for request fulfillment and curtailing the energy expenditure necessitated by the process. This equilibrium hinges on the culmination of various temporal dimensions:

1. **Waiting Time**: Capturing the period a user patiently awaits their chosen elevator post-request, factoring in the congestion and demand during that interval.

2. **Riding Time**: Encompassing the duration it takes for the allocated elevator to transport the user to their desired floor, integrating velocity and distance considerations.

3. **Stopping Time**: Factoring in the temporal overhead incurred due to the elevator's door operations, a variable dependent on situational factors such as crowd density.

4. **Distance travelled**: the distance travelled by an elevator.

This ensemble of temporal intricacies is synthesized into a holistic evaluation, whereby each available elevator's performance is scrutinized for optimal allocation. Through this meticulous process, our solution ensures that the chosen elevator for a specific request strikes an optimal balance between time efficiency and energy conservation.

When a user initiates a request through the panel, the system orchestrates a symphony of algorithms and data analysis. This symphony culminates in a judicious selection of the most suitable elevator, situated in the lobby, to cater to the user's beckoning. The server, acting as the conductor of this symphony, factors in the complex interplay of historical patterns, elevator availability, time dynamics, and energy consumption to orchestrate an efficient, seamless, and rapid elevator experience for the user.

In the pages that follow, we delve deeper into the intricate mechanics of our solution. We explore the nuances of AI integration, delve into the underpinnings of deep learning and machine learning models, dissect the algorithms orchestrating elevator allocation, and elucidate the orchestration of energy-efficient operations. Through this discourse, we aim to showcase not just a system, but a paradigm shift in elevating user experiences within corporate spaces through the amalgamation of AI and elevator management.

3.3 Work Breakdown Structure

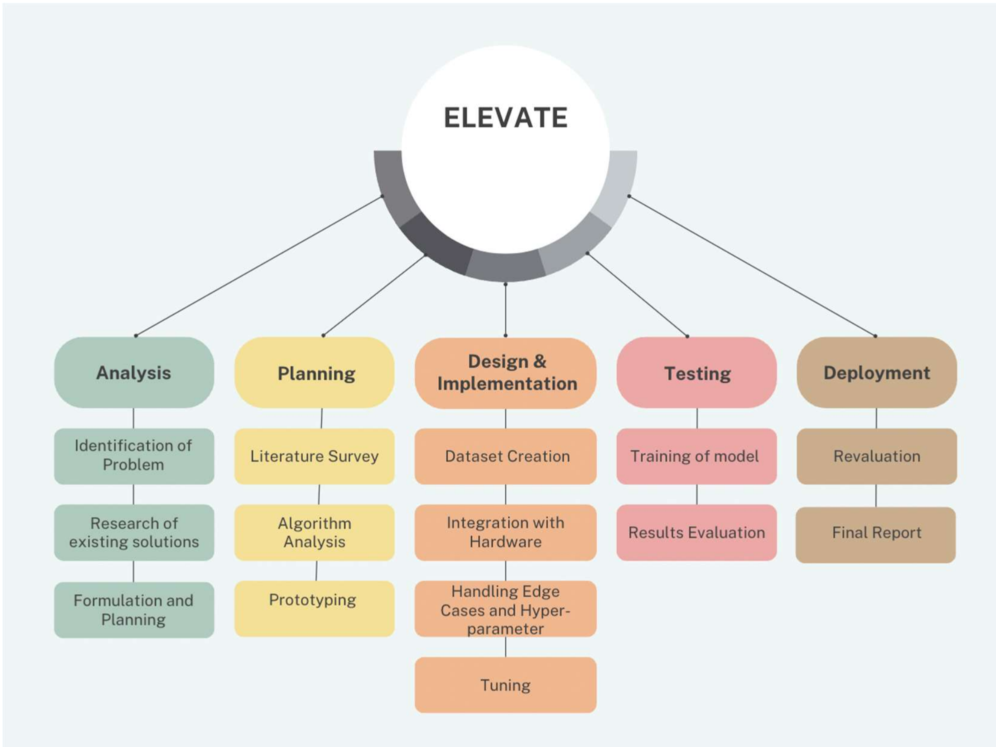


Figure 3.3.1: Work Breakdown

3.4 Tools and Technology Used

In the development of our intelligent elevator group management system, we leverage an array of advanced tools and state-of-the-art technologies to ensure seamless, adaptive, and user-centric elevator operations. This section provides an overview of the pivotal tools and technologies that form the backbone of our system.

Utilizing AI and Machine Learning Frameworks

To enable continuous learning and real-time adjustments, our system harnesses renowned AI and machine learning frameworks, including TensorFlow and scikit-learn. These frameworks serve as the structural foundation for implementing sophisticated algorithms that analyze data streams, predict traffic trends, and optimize elevator allocation.

Simulating Integration with Coral Module in Existing Lift Systems using Arduino Uno

The implemented algorithm seamlessly integrates with lift systems using the Coral module, providing a streamlined solution for elevators. Additionally, we have successfully simulated this integration using Arduino Uno, ensuring compatibility and functionality in diverse environments.

By amalgamating this diverse spectrum of tools and technologies, our intelligent elevator group management system emerges as a robust solution. It is dedicated to optimizing elevator operations, enhancing user experiences, and driving advancements in building automation and management practices.

4. DESIGN SPECIFICATIONS

4.1 System architecture

The project will blend MVC, Layered, and Event-driven architecture.

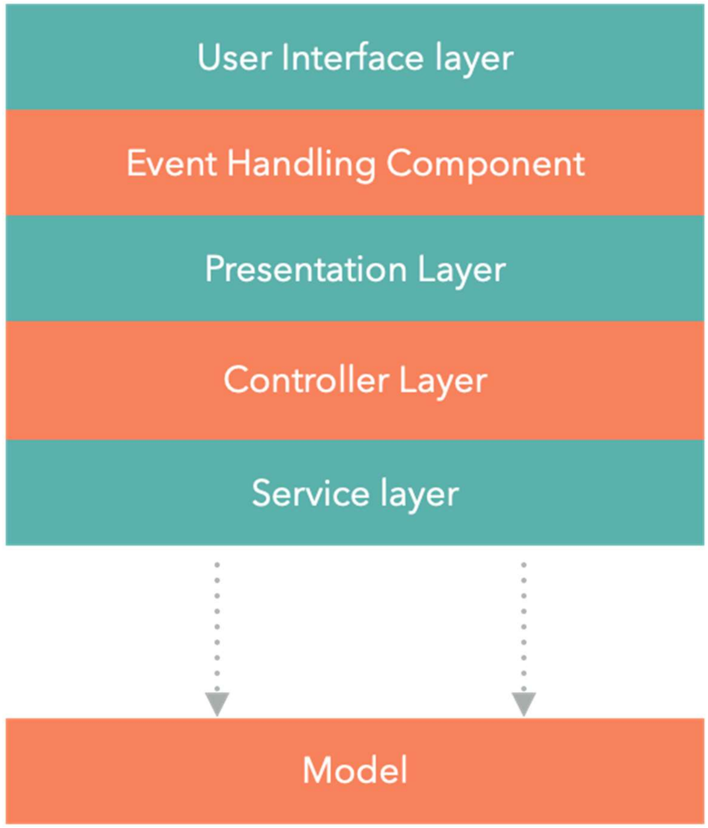


Figure 4.1.1: Layered System Architecture

In this architecture, the lift management system is divided into layers, each with a specific responsibility:

1. **User Interface Layer**: This layer provides the user interface for the system, including the screens and controls for selecting the destination floor and viewing lift status.

2. **Event Handling Component**: This component receives user input and other events, and converts them into commands that can be processed by the system.

3. **Presentation Layer**: This layer is responsible for presenting data to the user, such as the available lifts and their status.

4. **Controller Layer**: This layer contains the business logic for the system, including the algorithms for assigning lifts to users and the real-time trend analysis.

5. **Service Layer**: This layer provides access to the underlying data and resources

needed by the system, such as the sensors and actuators that control the lifts.

6. **Model**: This component represents the data and business logic of the system.

The arrows in the diagram represent the flow of data and control between the components. User input and other events are received by the Event Handling Component, which sends commands to the Controller Layer.

The Controller Layer processes these commands and updates the Model and Service Layer as needed. The Presentation Layer then retrieves data from the Model and presents it to the user through the User Interface Layer.

This architecture is Layered and Event-driven because it separates the system into different layers of responsibility and uses events to communicate between them. It is also MVC because the Model, View, and Controller components are present and interact with each other.

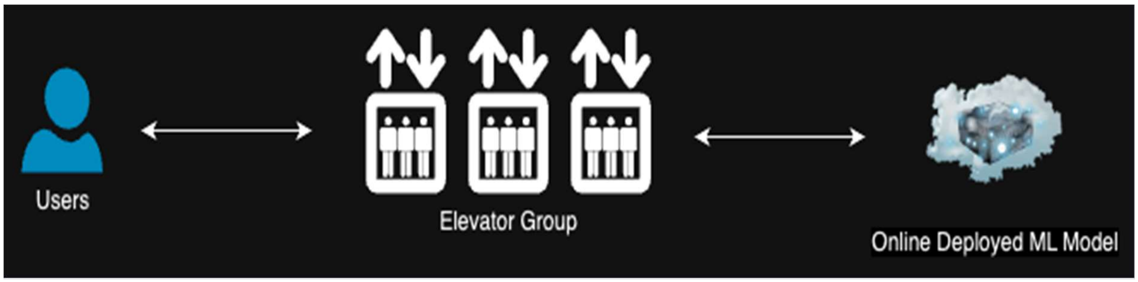


Figure 4.121:Interaction of various components in the project

1. **User Interface (UI):** This component is responsible for interacting with the users of the system. It receives user input and displays output to the users.

2. **Controller**: This component receives input from the UI and passes it on to the appropriate component for processing. It also sends output back to the UI.

3. **Business Logic**: This component contains the core functionality of the system. It processes input from the controller and produces output that is returned to the controller.

4. **Model**: This component contains the data and data-related functionality of the system. It is responsible for retrieving data from the database, processing it, and storing it back to the database.

5. **Services**: This component provides additional functionality to the system, such as sending notifications to external systems.

6. **Data Access**: This component interacts with the database to retrieve and store data.

7. **Database**: This component stores all the data used by the system.

- The components are organized into layers based on their responsibilities.
- The UI and controller are in the presentation layer.
- The business logic and services are in the application layer.
- The model and data access are in the data layer.
- The diagram shows the dependencies and relationships between the components.

4.2 Design level Diagrams

1. DFD

DFD, or Data Flow Diagram, is a visual representation that illustrates how data flows within a system and how processes transform that data. It is a widely used technique in system analysis and design. In a DFD, processes are represented as circles, data stores as rectangles, external entities as ovals, and data flows as arrows. The primary purpose of a DFD is to provide a clear and concise overview of the flow of data through a system, showing how inputs are processed to produce outputs. It helps in understanding the data requirements and interactions within a system at a high level.

LEVEL 0

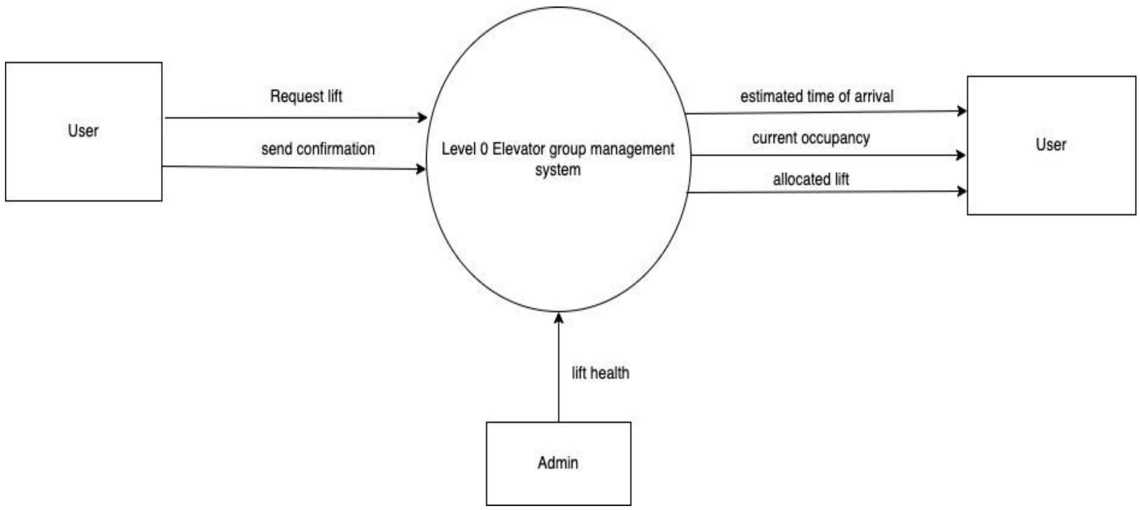


Figure 4.2.1: Level 0 DFD

LEVEL 1

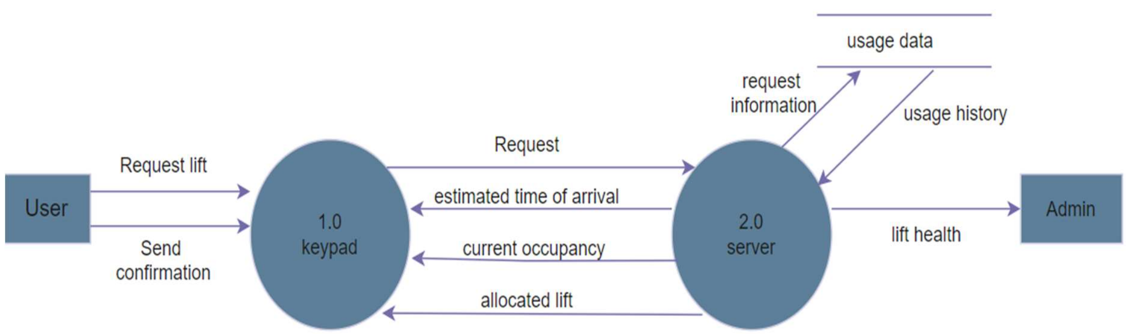


Figure 4.2.2: Level 1 DFD

Data Flow Diagram (DFD) Explanation: Lift Management System

The Data Flow Diagram (DFD) illustrates the data flow and interactions within the Lift Management System, which facilitates efficient elevator operation and user interaction. The system involves two main entities: users and administrators, and encompasses processes like requesting a lift and receiving relevant information about the elevator's status.

Entities:

User: Represents building occupants who request elevator services.

Admin: Represents administrators responsible for overseeing and managing the lift system.

Processes:

Requesting Lift: The User initiates the process by requesting a lift through an interface. This process takes the user's request and passes it to the system for further handling.

Estimating Arrival Time: Once the request is received, the system calculates the estimated arrival time for the requested elevator to the user's location. This process considers elevator positions and current movement.

Allocating Lift: Based on the user's request and the elevator's current statuses, the system allocates a specific elevator to respond. The allocation process takes into account factors like elevator proximity and occupancy.

Providing Information: After allocation, the system returns information to the user. This information includes the estimated time of arrival, occupancy status (whether the elevator is empty, partially occupied, or full), and the allocated lift number.

Administrator Management: The Admin entity interacts with the system for management purposes. This could involve tasks like adding new elevators to the system, adjusting parameters for allocation, or monitoring overall system performance.

Data Flows:

User Request: Data flow from the User to the Requesting Lift process, containing the user's request for a lift.

Allocated Lift Information: Data flow from the Allocating Lift process to the Providing Information process, conveying information about the allocated elevator (estimated time of arrival, occupancy, and lift number).

System Information: Data flow from the Admin to the Administrator Management process, providing administrative inputs and adjustments.

System Status: Data flow from the various processes (Estimating Time of Arrival, Allocating Lift) to the Admin, allowing administrators to monitor the overall system status.

Data Flow Descriptions:

When a User initiates a lift request, it triggers the Requesting Lift process. This process takes the user's request and forwards it for further processing.

The Estimating Time of Arrival process calculates an estimated time based on the current positions and movements of elevators.

The Allocating Lift process determines the best-suited elevator for the user's request and passes this information to the Providing Information process.

The Providing Information process packages the allocated lift's details, such as estimated time of arrival, occupancy, and lift number, and provides this information back to the User.

The Administrator Management process handles administrative tasks initiated by the Admin entity, maintaining control over the system's configuration and performance.

This DFD offers a clear visual representation of the Lift Management System's flow, enabling both users and administrators to understand the interactions and data exchanges that drive efficient elevator operation and user satisfaction.

2. Class Diagram

A class diagram is a type of UML (Unified Modeling Language) diagram that provides a visual representation of the structure and relationships among classes within a system or software application. It illustrates the attributes, methods, and associations associated with each class, showcasing how objects in the system interact and collaborate. Class diagrams are fundamental for modeling the static structure of a system, aiding in the understanding and design of object-oriented systems.

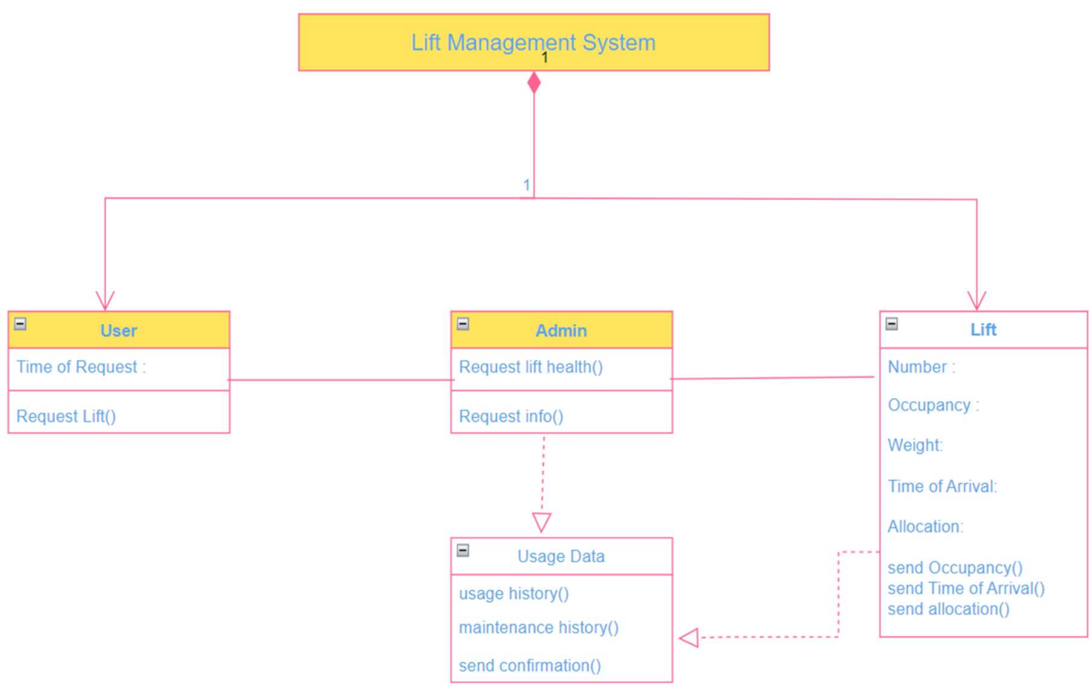


Figure 4.2.3: Class Diagram

Class Diagram Explanation: Lift Management System

User Class:

Attributes:
timeOfRequest: Stores the time when the user requested a lift.
Methods:
requestLift(): Initiates a request for a lift.
Admin Class:

Attributes: None
Methods:
manageSystem(): Allows the admin to manage system settings and parameters.
monitorSystem(): Provides the admin with the ability to monitor the overall system status.
Lift Class:

Attributes:
occupancy: Represents the number of people inside the lift.
weight: Indicates the current weight load of the lift.
number: Lift identifier.
timeOfArrival: Records the estimated time of arrival for the lift to a requested floor.
allocation: Stores the lift allocation number.
Methods:
move(): Handles the movement of the lift.
updateStatus(): Updates the status of the lift, including occupancy and weight.
allocateLift(User user): Allocates the lift to a specific user's request.
estimateTime(User user): Calculates the estimated time of arrival for the lift to the user's location.
UsageData Class:

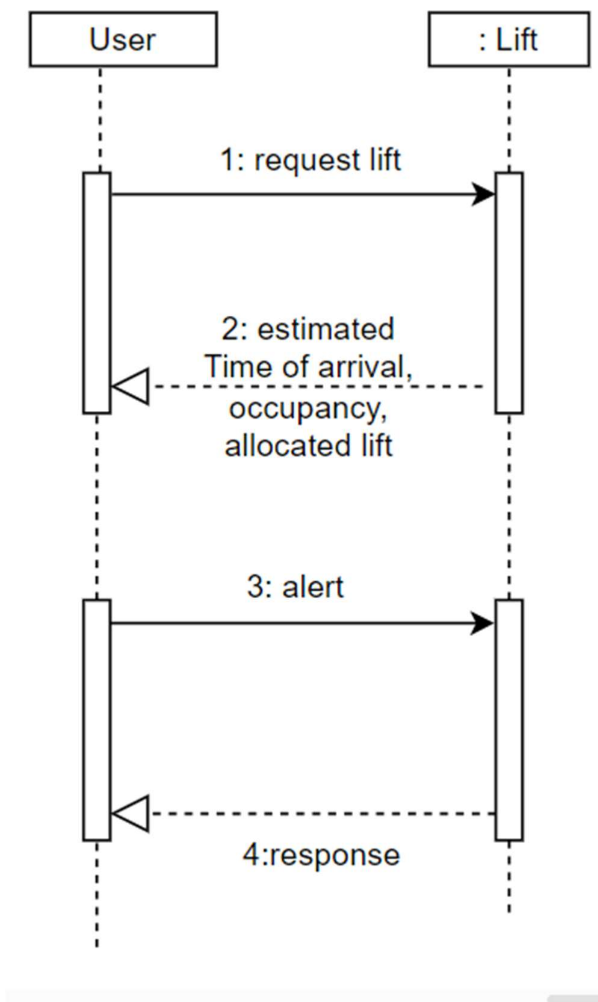
Attributes: None
Methods:
recordUsage(User user, Lift lift): Records the usage data, associating a user with a specific lift.
generateReport(): Generates usage reports and statistics for analysis.
Relationships:

User - RequestingLiftProcess: Indicates that a user initiates a lift request.
RequestingLiftProcess - Lift: Depicts that the lift is allocated in response to a user's request.
Lift - AllocatingLiftProcess: Represents the connection between lift attributes and the lift allocation process.
Lift - ProvidingInfoProcess: Demonstrates that lift attributes contribute to providing information to the user.
Admin - AdminManagementProcess: Illustrates the admin's ability to manage the system through administrative processes.
AdminManagementProcess - Lift: Shows the relationship between administrative processes and lift management.
Lift - UsageData: Indicates that usage data is associated with a specific lift.

User - UsageData: Shows the relationship between users and their recorded usage data. This Class Diagram captures the key components of the Lift Management System, including the classes, their attributes, methods, and the relationships between them. It highlights how users, administrators, lifts, and usage data interact within the system, facilitating efficient elevator operations and data tracking.

3. Sequence Diagram(for User & Admin)

A sequence diagram is a visual representation in UML that depicts the dynamic interactions between objects or components in a system. It shows the sequence of messages exchanged over time, using lifelines to represent objects and arrows to indicate message flow. This diagram helps illustrate the chronological order of interactions and system behavior during various scenarios or use cases.



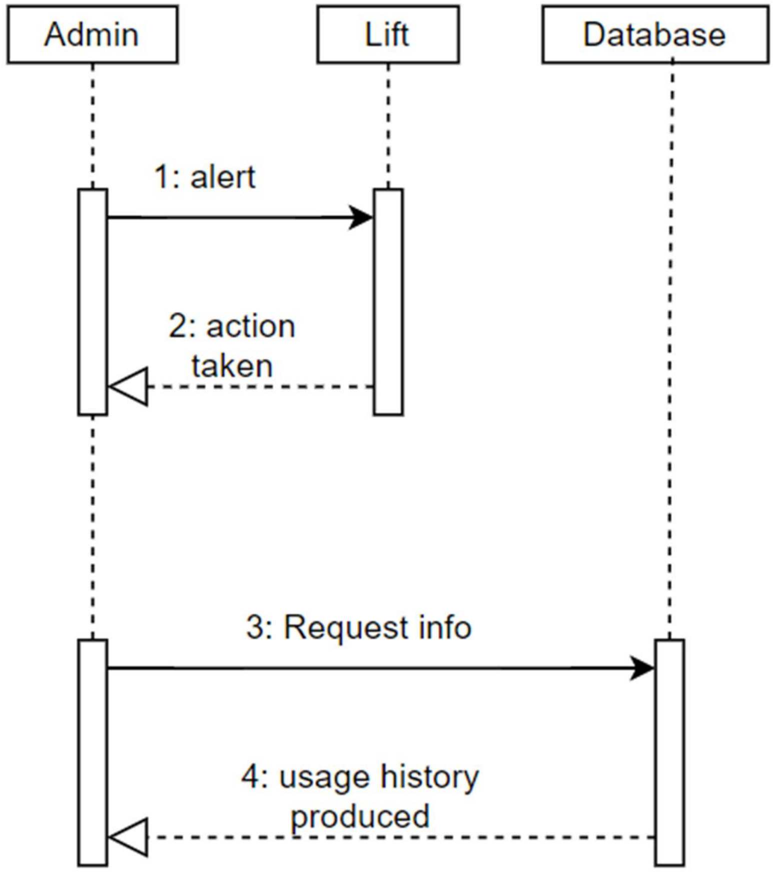


Figure 4.2.4: Sequence Diagram

Sequence Diagram Explanation: Lift Management System (with Emergency Alert)

User Requests Lift:

The User initiates a lift request by calling the requestLift() method.

The User class sends a message to the Lift class to initiate the process.

The Lift class responds by triggering the allocateLift(User user) method.

The Lift class communicates with the Admin class to check for lift allocation rules.

The Admin class responds to the Lift class.

User Activates Emergency Alert:

While inside the lift, the User can activate the activateEmergencyAlert() method in case of an emergency.

The User class sends an emergency alert message to the Lift class.

The Lift class reacts by informing the Admin class about the emergency.

The Admin class can take appropriate actions like notifying emergency services.

Lift Provides Information:

The Lift class calculates the estimated time of arrival by calling the estimateTime(User user) method.

The Lift class communicates with the User class, providing the estimated time of arrival and other lift information.

The User class responds by acknowledging the information.

Admin Manages System:

The Admin initiates the management process by calling the manageSystem() method.

The Admin class communicates with the AdminManagementProcess, which interacts with the Lift class to adjust parameters or monitor status.

Admin Activates Emergency Alert:

The Admin can initiate an emergency alert using the activateEmergencyAlert() method.

The Admin class sends an emergency alert message to the Lift class, notifying about the emergency situation.

The Lift class responds by checking its status and alerting the User inside the lift.

The User class can respond accordingly, acknowledging the emergency alert.

Recording Usage Data:

The Lift class records usage data by calling the recordUsage(User user, Lift lift) method in the UsageData class.

The UsageData class records the usage data and associates it with the corresponding User and Lift instances.

Generating Reports:

The UsageData class generates usage reports and statistics by calling the generateReport() method.

The UsageData class communicates the generated reports to the Admin class or other relevant parties.

User Monitoring System:

The User can monitor the system by requesting status updates using the monitorSystem() method.

The User class communicates with the Admin class, which can respond with the current system status.

This enhanced Sequence Diagram now includes interactions related to the "Emergency Alert" feature for both the User and Admin classes, showcasing how the system responds in case of emergencies.

4. Swimlane (Activity) Diagram

A swimlane diagram, also known as a cross-functional flowchart or swimlane flowchart, is a visual representation that divides a process or workflow into distinct lanes or "swimlanes," each assigned to a specific role, department, or participant involved in the process. These swimlanes clarify responsibilities and interactions by showing which entities are responsible for which tasks. The diagram is useful for illustrating cross-functional processes and promoting a better understanding of the flow of activities across different organizational units or individuals.

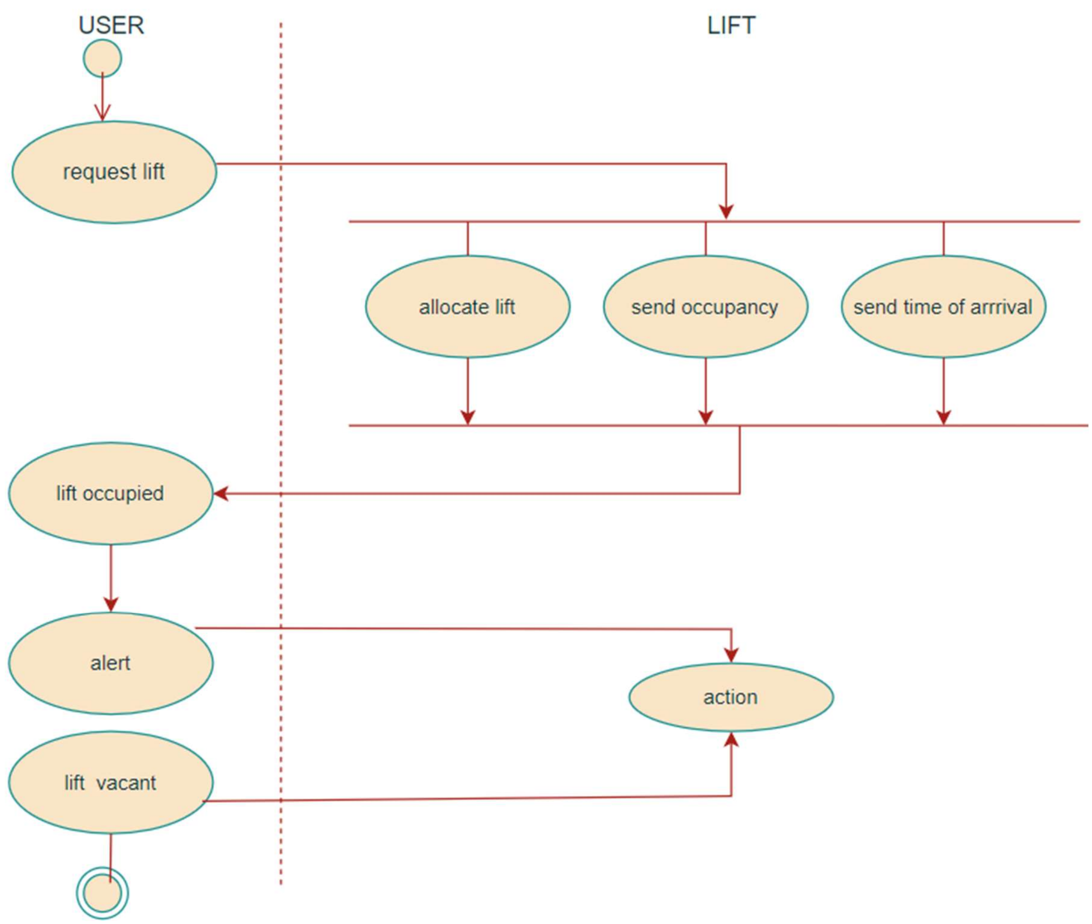


Figure 4.2.5: Swimlane Diagram

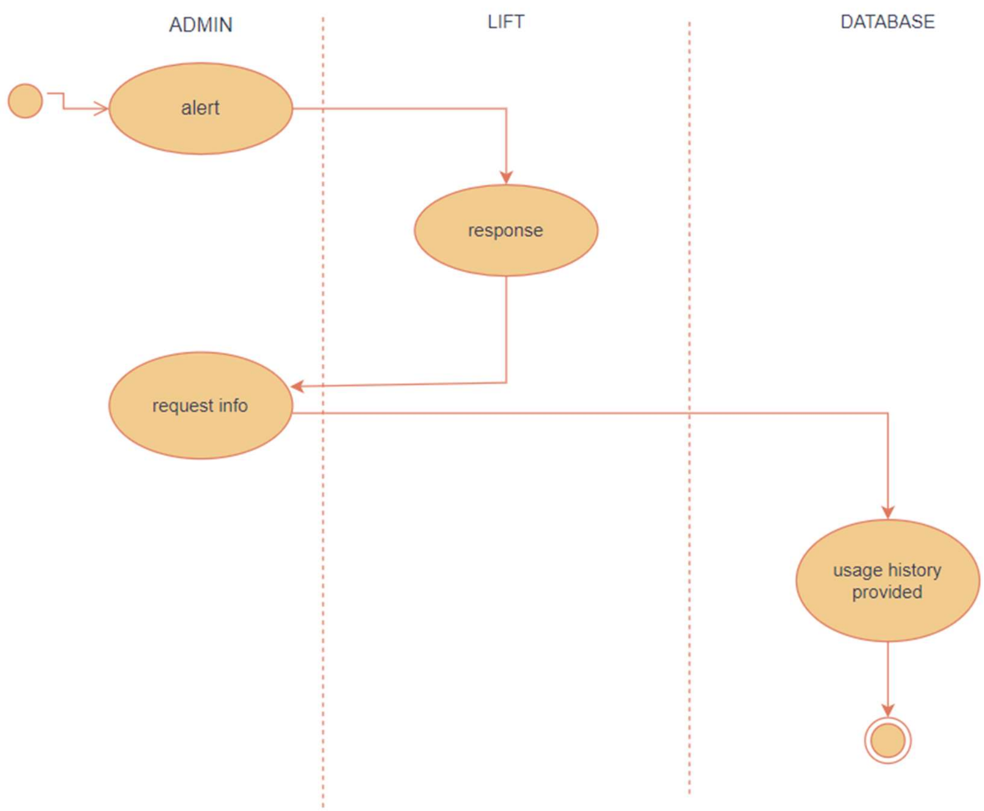


Figure 4.2.6: Swimlane Diagram

Swimlane Diagram Explanation: Lift Management System

In this Swimlane Diagram, each lane represents a different entity or role, and the interactions between these lanes depict the flow of activities and responsibilities.

Lanes:

User: Represents the actions and responsibilities of the users who interact with the system.

Admin: Represents the administrative roles responsible for managing the system.

Lift: Represents the actions and behaviors of the lift itself.

Usage Data: Represents the processes related to recording and generating usage reports.

Activities and Responsibilities:

User Lane:

Initiate Lift Request: The user initiates a lift request.

Activate Emergency Alert: The user can activate an emergency alert if needed.

Monitor System Status: The user can request system status updates.

Receive Lift Information: The user receives information about allocated lift, estimated time of arrival, etc.

Acknowledge Emergency Alert: The user acknowledges an emergency alert if activated.

Admin Lane:

Manage System: Admins manage system parameters and settings.

Activate Emergency Alert: Admins can activate emergency alerts.

Monitor System: Admins monitor the system status and performance.

Respond to Emergency: Admins respond to emergency alerts by taking appropriate actions.

Lift Lane:

Allocate Lift: The lift allocates itself based on user requests.

Estimate Time: The lift estimates the time of arrival for the requested floor.

Update Lift Status: The lift updates its status, including occupancy and weight.

Alert Admin: The lift alerts the admin in case of emergency activation.

Usage Data Lane:

Record Usage Data: The system records usage data, associating users with lifts.

Generate Reports: The system generates usage reports and statistics for analysis.

Interactions:

The User initiates lift requests, activates emergency alerts, and receives information from the Lift.

The Admin manages the system, activates emergency alerts, and responds to emergencies.

The Lift allocates itself, estimates time, updates its status, and communicates emergencies to the Admin.

The Usage Data processes record usage data and generate reports.

This Swimlane Diagram visually captures the interactions, activities, and responsibilities of different entities within the Lift Management System. It provides a clear overview of how each role contributes to the system's operation and management.

5. State Diagram

A state chart diagram is a visual representation in UML depicting the dynamic behavior of a system or entity. It illustrates different states, transitions between states, events, and activities, providing a concise overview of the system's behavior and lifecycle.

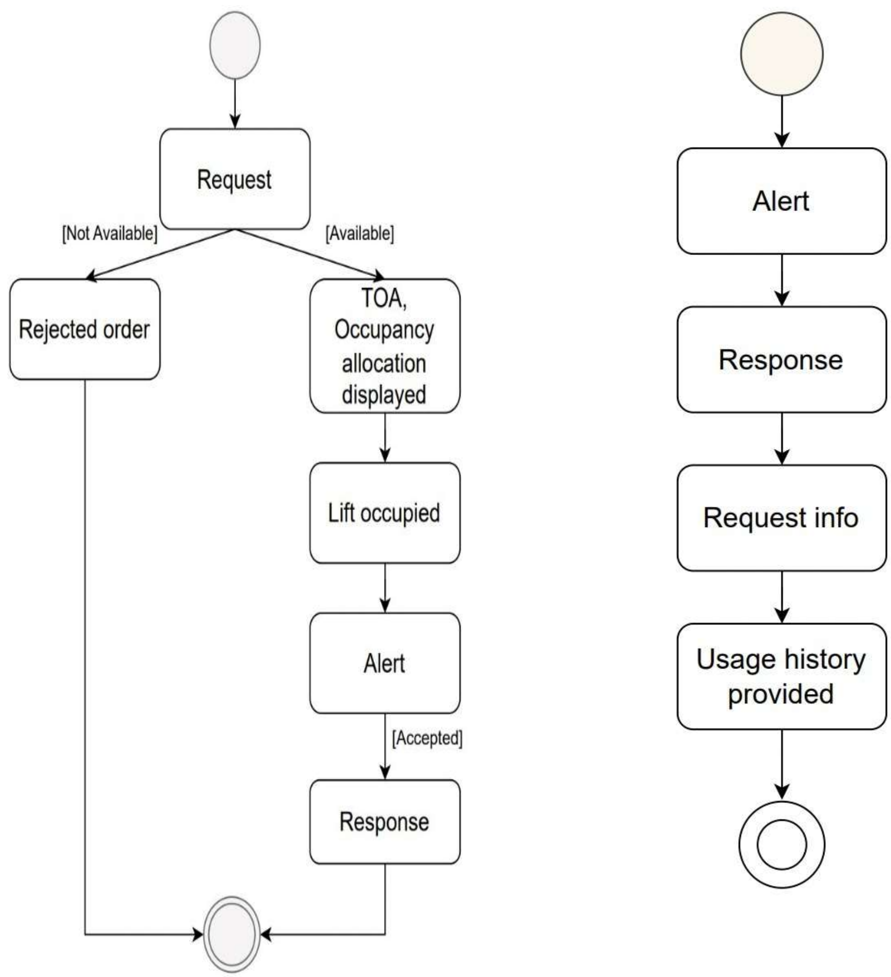


Figure 4.2.7: State Diagram for User & Admin

State Chart Diagram Explanation: Lift Management System (User Side)

States:

Idle: The initial state, where the User is not requesting a lift.

Requesting: The User has requested a lift and is waiting for availability information.

Lift Available: The User has been provided information about the available lift.

Events:

Request Lift: The User initiates a lift request.

Lift Available: The Lift is available for allocation.

Transitions:

Idle -> Requesting: Transition triggered when the User requests a lift. Moves to the "Requesting" state.

Requesting -> Lift Available: Transition triggered when the Lift becomes available. Moves to the "Lift Available" state.

Lift Available -> Idle: Transition triggered when the User acknowledges the lift information and returns to the idle state.

When the Lift becomes available and the User is in the "Lift Available" state, the following information is provided to the User:

Lift Number: The identifier of the available lift that will respond to the User's request. For example, "Lift 2".

Occupancy Status: Information about the current occupancy status of the lift, indicating whether the lift is empty, partially occupied, or full.

Estimated Time of Arrival: The estimated time when the available lift will reach the User's location, giving an approximation of when the lift will be ready for the User to board.

4.3 User Interface Diagrams

Use case Diagram

A use case diagram is the primary form of system/software requirements for a new software program underdeveloped. Use cases specify the expected behaviour (what), and not the exact method of making it happen (how). It is an effective technique for communicating system
behaviour in the user's terms by specifying all externally visible system behaviour.

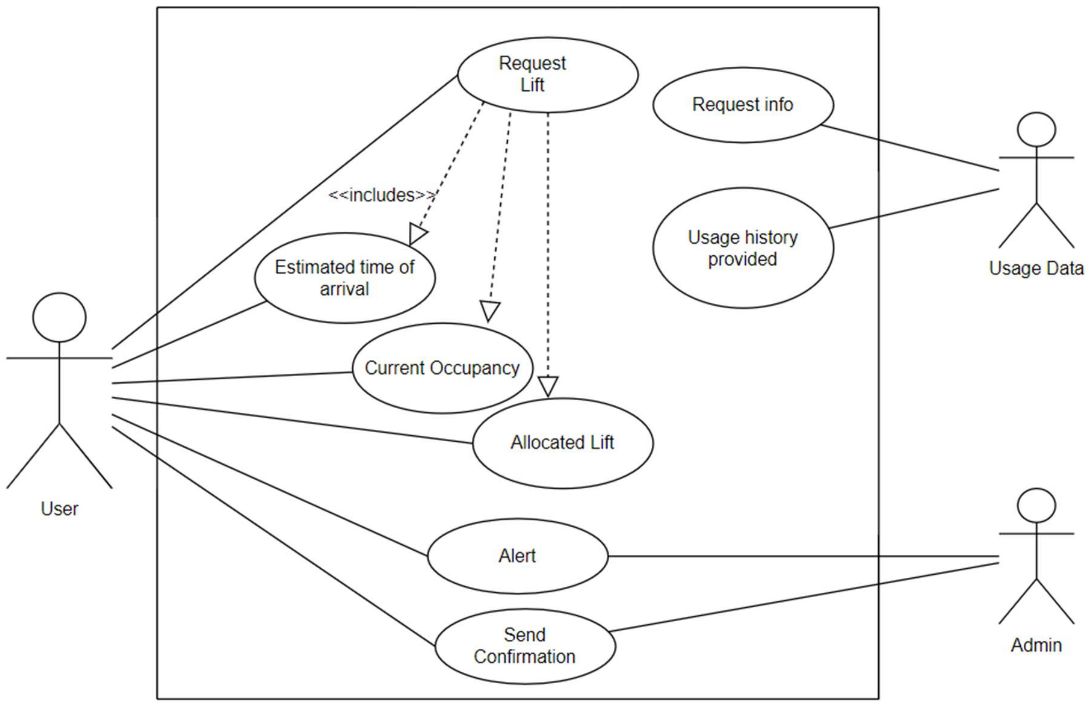


Figure 4.2.8: Use case diagram

Use Case Diagram Explanation: Lift Management System

Actors:

User: Represents the building occupants who interact with the lift system.

Admin: Represents the administrators responsible for managing the system.

Usage Data: Represents the entity responsible for recording and generating usage reports.

Use Cases:

Request Lift:

Actor: User

Description: The user initiates a request to call a lift to their current floor.

Associated Features: Allocation of an available lift, estimating time of arrival.

Provide Lift Information:

Actor: System

Description: The system provides the lift number, occupancy status, and estimated time of arrival to the user.

Associated Features: Displaying lift information for user convenience.

Send Alerts:

Actor: User, Admin

Description: Users and administrators can trigger emergency alerts in case of emergencies.

Associated Features: Notifying relevant parties about emergency situations.

Access Reports:

Actor: Admin

Description: Administrators can access and generate usage reports and statistics.

Associated Features: Monitoring system performance and usage patterns.

Record Usage Data:

Actor: Usage Data

Description: Usage Data records user-lift associations for usage tracking.

Associated Features: Capturing usage patterns for analysis.

Generate Reports:

Actor: Usage Data

Description: Usage Data generates usage reports and statistics.

Associated Features: Creating insights and reports based on captured usage data.

Relationships:

User - Request Lift: The user initiates the "Request Lift" use case.

User - Send Alerts: The user can trigger emergency alerts.

Admin - Send Alerts: Administrators can also trigger emergency alerts.

Admin - Access Reports: Administrators access and generate reports.

Usage Data - Record Usage Data: The "Usage Data" actor records user-lift associations.

Usage Data - Generate Reports: The "Usage Data" actor generates usage reports.

Use Case Template

A use case template is a standardized document format used to outline and describe the functionality, interactions, and steps involved in a specific action or scenario within a system or software application. It typically includes key elements such as actors, preconditions, main flow, alternative flows, postconditions, and exceptional cases. The template serves as a guide for documenting and understanding specific use cases during the software development or systems engineering process.

ID:	[1000]
Title:	AllocateLift
Description:	The AllocateLift use case efficiently allocates elevators for floor requests, optimizing response times and enhancing user experience in the lift management system.
Primary Actor:	User: Initiates the request for elevator allocation by selecting a floor.
Preconditions:	• The lift management system is operational. • Elevators are available for allocation. • The user has input a valid floor request.
Postconditions:	• The elevator is successfully allocated to the requested floor. • The lift management system updates its status to reflect the allocation.
Main Success Scenario:	• System processes the input. • Analyzes current elevator status. • Identifies the most suitable elevator. • Dispatches the selected elevator. • User receives notification of elevator's arrival and floor assignment.
Extensions:	• Invalid floor request: System provides feedback for invalid input. • No available elevators: System informs user of unavailability.
Modification History:	18 NOV 2023
Owner:	Chahat Joneja

ID:	[2000]
Title:	ActivateEmergencyAlert
Description:	The ActivateEmergencyAlert use case triggers an emergency alert in the lift management system, initiated by the administration in response to a crisis. This prompts an immediate halt to all lift activities, safely stopping elevators on the nearest floor. The system remains inactive until authorized personnel press the reset button, enabling a controlled resumption of lift operations.
Primary Actor:	• Administration: Initiates the emergency alert and resets the system.
Preconditions:	• The lift management system is operational. • Emergency alert conditions have been defined by the administration. • The reset button is available and accessible.
Postconditions:	• The emergency alert is successfully activated, and all lift activities are halted. • Elevators are safely stopped on the nearest floor. • The lift management system remains in an emergency state until authorized personnel press the reset button.
Main Success Scenario:	• The administration declares an emergency, activating the emergency alert within the system. • All lift activities come to an immediate stop, and elevators safely halt on the nearest floor. • The emergency alert is communicated to all relevant stakeholders through predefined channels. • The lift management system remains in a paused state until the reset button is pressed by authorized administration personnel. • Upon pressing the reset button, the system verifies the authorization and begins the process of resuming normal lift operations.
Extensions:	• Reset Authorization Failure:If the reset button is pressed by an unauthorized person, the system denies the reset request and maintains the emergency state.
Modification History:	25 NOV 2023
Owner:	Jahnvi Gangwar

5: IMPLEMENTATION AND EXPERIMENTAL RESULTS

5.1 Experimental Setup (or simulation)

The experimental setup for our Lift Management System (LMS) involves a comprehensive integration of advanced mechanisms aimed at optimizing elevator performance and user experience. In this innovative system, we employ cutting-edge technologies, including sensors, actuators, and a robust central processing unit. The LMS is designed to display crucial information such as estimated time of arrival at each floor and current occupancy levels. What sets our system apart is its ability to autonomously learn and adapt using reinforcement learning. Through this intelligent mechanism, the lift system learns and refines its operations over time, ensuring that it automatically reaches the desired floor at the specified time. This adaptive capability not only enhances efficiency but also contributes to a more seamless and user-centric elevator experience. By combining state-of-the-art hardware with intelligent algorithms, our experimental setup seeks to revolutionize lift management, providing a glimpse into the future of smart and responsive vertical transportation systems.

5.2 Experimental Analysis

5.2.1 Data (Data Sources/Data Cleaning/Data Pruning/ Feature Extraction Workflow)

The experimental analysis of Lift Management Systems involves a meticulous selection of data sources, considering the challenges posed by leading lift algorithm manufacturers' reluctance to share sample datasets due to regulatory compliance constraints. In response to this limitation, we adopted a strategic approach to construct datasets that mimic real-world scenarios, allowing for a robust evaluation of lift algorithms.

Data Sources:

Manual Dataset Creation:

Description: In the absence of readily available datasets, we manually curated a dataset by simulating various lift scenarios, considering factors such as user arrivals, floor requests, and system responses.
Purpose: Facilitates the generation of controlled data for initial algorithm testing and validation.

First Observations of Real-Time Data:

Description: Initial observations of real-time lift system data were used to create a small dataset capturing the nuances of user behavior, elevator occupancy, and response times.
Purpose: Provides a foundation for understanding actual system dynamics and informs the creation of more realistic datasets.

Research Paper Findings as Time Series Data:

Description: Leveraging insights from research papers on lift elevator algorithms, we extracted and utilized time series data patterns to construct synthetic datasets.
Purpose: Incorporates validated algorithmic behaviors into the dataset to assess their performance under various conditions.

Challenges:

The primary challenge faced during data collection was the industry's reticence in sharing proprietary datasets. As a result, the approach of manually creating datasets and incorporating real-time observations became essential to bridge the data gap and facilitate meaningful experimentation.

Conclusion:

While the unavailability of manufacturer-provided datasets posed challenges, the adopted methodology ensures a comprehensive analysis by combining manually crafted datasets, real-time observations, and algorithmic findings from research papers. This multi-faceted approach enables a robust evaluation of lift management algorithms, contributing valuable insights to the experimental analysis of Lift Management Systems.

Data Cleaning/Data Pruning

Data Collection:
In the initial phase of our experimental analysis for the Lift Management System, we systematically collected a diverse set of attributes to comprehensively capture the system's behavior. These attributes included user inputs, elevator response times, floor requests, system logs, energy consumption data, and various operational parameters.

Data Combination:
To enhance the efficiency of our analysis, we combined certain attributes, recognizing their interdependencies. For example, user wait times and elevator travel times were integrated to create a holistic view of the passenger experience. This step aimed at simplifying the dataset structure without sacrificing critical information.

Attribute Removal:
A crucial aspect of the data cleaning process involved the removal of situation-specific or irrelevant attributes that did not contribute significantly to the experimental goals. This step helped streamline the dataset, focusing on the most pertinent features for evaluating lift management algorithms.

Outlier Removal:
Identifying and handling extreme outlier conditions was imperative to ensure the reliability of our experimental analysis. Instances where the elevator system could potentially fail or exhibit anomalous behavior were systematically removed from the dataset. This step aimed at preventing skewed results and aligning the data with realistic operational scenarios.

Data Pruning:
To further refine the dataset, a pruning process was implemented. This involved a careful examination of the remaining data points to eliminate redundancy and maintain data integrity. Pruning ensured that the dataset remained representative of the lift management system's typical behavior, minimizing any distortions introduced during data collection.

Challenges and Considerations:
Data cleaning and pruning posed challenges due to the dynamic nature of elevator systems. Continuous monitoring and iterative adjustments were essential to accommodate evolving system behaviors and adapt to unforeseen patterns.

Conclusion:
The meticulous process of data cleaning and pruning in our experimental analysis of the Lift Management System has yielded a refined dataset, optimized for assessing the performance of various lift algorithms. By combining, removing, and pruning attributes, we have ensured that the dataset is both comprehensive and representative, setting the stage for robust and meaningful analysis of lift management algorithms under realistic conditions.

Feature Extraction Workflow

Normalization Process:
In the Experimental Analysis of the Lift Management System, a crucial step following data cleaning and pruning was the normalization of the dataset. Normalization is vital to ensure that all features are on a comparable scale, preventing certain attributes from disproportionately influencing the analysis due to differences in magnitude.

Relevant Generated Attributes:
Beyond the original dataset, we incorporated additional relevant attributes through a feature generation process. These attributes were derived from the existing dataset or generated to capture specific aspects of the lift management system's behavior. For instance, metrics like the average waiting time per floor or the rate of energy consumption during peak hours were introduced to provide a more nuanced understanding of system performance.

Feature Engineering:
The process of feature extraction involved transforming raw data into a set of features that best represented the underlying characteristics of the lift management system. This step aimed to enhance the dataset's informativeness and facilitate more nuanced analysis. Features were engineered to capture patterns, trends, and dependencies within the data, ensuring a comprehensive representation of the system's dynamics.

Attribute Normalization:
Normalization was performed on the entire dataset, including both original and generated attributes. This process involved scaling numerical values to a standard range, such as [0, 1], to eliminate any bias introduced by varying units or scales. Normalized attributes allow for fair comparisons between different features and contribute to the overall accuracy of the experimental analysis.

Challenges and Considerations:
Normalization challenges included dealing with skewed distributions and outliers, necessitating careful selection of normalization techniques. Additionally, ensuring that the

normalization process did not inadvertently distort the intrinsic characteristics of the dataset was a critical consideration.

Conclusion:
Feature extraction, normalization, and the addition of relevant generated attributes have collectively refined the dataset for our Experimental Analysis of the Lift Management System. By incorporating these steps, we have established a standardized, comprehensive, and representative set of features that will contribute to a more accurate and insightful evaluation of lift management algorithms. The normalized and enriched dataset is now poised for in-depth analysis and meaningful interpretation of the lift system's performance.

5.2.2 Performance Parameters (Accuracy Type Measures/ QOS Parameters depending upon the type of project)

Introduction:
Evaluating the performance of a Lift Management System (LMS) involves assessing various critical parameters that collectively determine the system's efficiency, user experience, and overall reliability. In this comprehensive report, we delve into key performance indicators, emphasizing Average Waiting Time, Average Riding Time, Number of Stops, Shortest Distance, Long Waiting Times Count, Reliability and Availability, Energy Efficiency, and Handling Capacity.

1. Average Waiting Time:

Definition: The average duration passengers spend waiting for an elevator.

Importance:

- Reflects the responsiveness and efficiency of the lift allocation algorithm.
- Minimizing waiting time contributes to improved user satisfaction.

Analysis: A lower average waiting time enhances the overall user experience, indicating an optimized system that efficiently allocates elevators in response to user demands.

2. Average Riding Time:

Definition: The average duration passengers spend inside the elevator from entry to exit.

Importance:

- Influences user comfort and satisfaction.
- Affects system throughput and efficiency.

Analysis: Balancing average riding time ensures optimal elevator capacity usage, contributing to enhanced system efficiency and user satisfaction.

3. Number of Stops:

Definition: The total count of stops made by an elevator during a specific time period.

Importance:

- Influences energy consumption and system wear.
- Indicates the effectiveness of the elevator routing algorithm.

Analysis: A lower number of stops contributes to energy efficiency and reduced travel time, highlighting the effectiveness of the elevator routing strategy.

4. Shortest Distance:

Definition: The minimum travel distance covered by elevators to fulfill passenger requests.

Importance:

- Affects energy efficiency and system wear.
- Indicates the efficiency of the routing algorithm in minimizing travel distances.

Analysis: Optimizing for the shortest distance contributes to energy conservation and reduced elevator wear and tear, enhancing overall system efficiency.

5. Long Waiting Times Count:

Definition: The number of instances where passengers experience waiting times beyond a predefined threshold.

Importance:

- Reflects on user dissatisfaction and system responsiveness.
- Helps identify periods of peak demand or potential algorithmic inefficiencies.

Analysis: A high count of long waiting times indicates potential areas for improvement in system responsiveness, guiding refinements to the lift allocation algorithm.

6. Reliability and Availability:

Definition: The percentage of time the elevator system is operational and available for use.

Importance:

- Crucial for maintaining uninterrupted service.
- Impacts user confidence in the system.

Analysis: High reliability and availability percentages are indicative of a robust system that consistently meets user needs and expectations.

7. Energy Efficiency:

Definition: The amount of energy consumed by the elevator system during operation.

Importance:

- Directly impacts operational costs and environmental sustainability.
- A measure of the system's environmental impact.

Analysis: Evaluating energy efficiency helps identify opportunities for optimization, reducing costs and environmental impact.

8. Handling Capacity:

Definition: The system's ability to transport passengers within a specified time period.

Importance:

- Influences the system's ability to handle peak traffic efficiently.
- Ensures optimal resource utilization.

Analysis: Assessing handling capacity provides insights into the system's ability to manage peak demand, guiding improvements for optimal resource utilization.

Conclusion:
A holistic evaluation of these performance parameters ensures a thorough understanding of the Lift Management System's effectiveness. By prioritizing user-centric metrics, reliability, energy efficiency, and handling capacity, stakeholders can make informed decisions to enhance overall system performance, responsiveness, and user satisfaction. Continuous monitoring and optimization of these parameters are essential for ensuring a reliable, efficient, and sustainable lift management system.

5.3 Working of the project

5.3.1 Procedural Workflow (at least one-page explanation with diagram)

The development of our intelligent lift management system involved a systematic procedural workflow encompassing various stages. Each stage played a crucial role in achieving a robust and efficient solution.

1. Literature Survey:

We began with an extensive literature survey to understand existing lift management systems, algorithms, and technologies. We analyzed research papers, industry reports, and case studies to gain insights into best practices and emerging trends in elevator optimization.

2. Prototyping and Algorithm Analysis:

We moved to the prototyping stage where we implemented initial algorithms in a simulated environment. We conducted algorithm analysis to assess their performance in handling various scenarios. This phase allowed for early identification of strengths and weaknesses in the proposed algorithms.

3. Observation Collection and Dataset Creation:

We initiated the collection of observations related to elevator usage patterns, traffic flows, and peak times. These observations served as the foundation for creating a comprehensive dataset. We utilized Google Colab for dataset creation and handling, ensuring efficient collaboration and data management.

4. Integration with Hardware:

We proceeded to integrate the algorithmic solutions with the hardware components of the lift system. We utilized Arduino for hardware integration. We ensured seamless communication between the intelligent system and the existing elevator infrastructure. This phase involved incorporating sensors and other hardware elements to enable real-time data exchange and algorithm implementation.

5. Handling Edge Cases and Hyper-parameter Tuning:

We addressed potential edge cases and scenarios that could challenge the effectiveness of the lift management system. We fine-tuned hyperparameters of the algorithms to optimize their performance across various conditions. This step was crucial in enhancing the adaptability and reliability of the system.

6. Training of Model:

We employed machine learning techniques to train predictive models using the collected dataset. We trained the model to recognize patterns, anticipate elevator demand, and adapt to changing traffic conditions. This phase involved leveraging historical data to enhance the system's predictive capabilities.

7. Testing of Project:

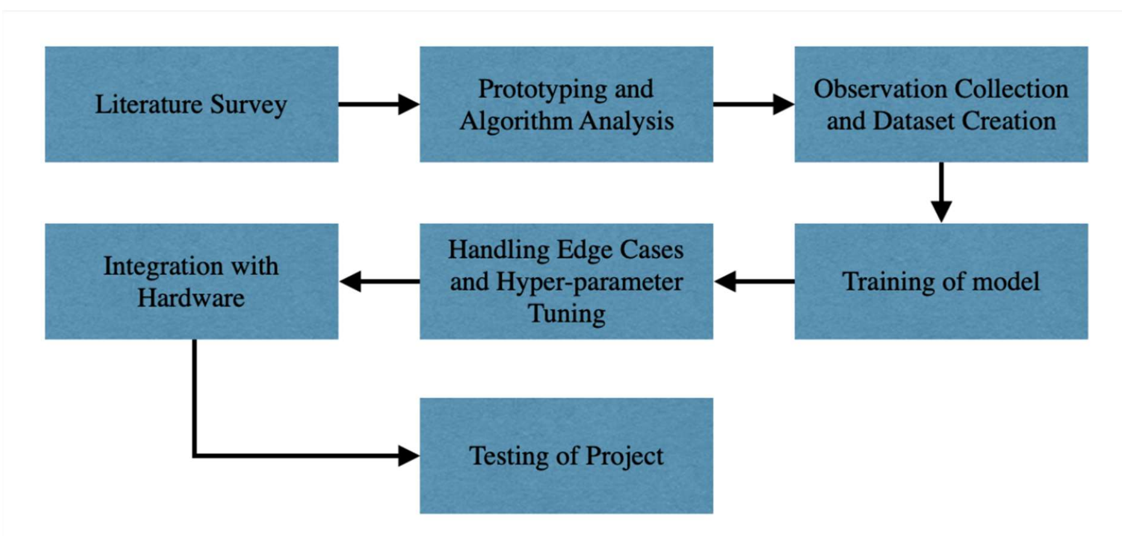
We conducted thorough testing of the integrated lift management system. While real-time testing was not performed, we simulated scenarios to evaluate its performance metrics, including wait times, ride times, energy consumption, and overall efficiency. Testing provided valuable insights into the practical effectiveness of the algorithms and their impact on user experience.

8. Report Generation:

We compiled the findings, observations, and results into a comprehensive final report. We included details on the implemented algorithms, hardware integration, dataset characteristics, and the overall performance of the lift management system. The report served as documentation of our project's methodology, outcomes, and contributions.

9. Revaluation:

We conducted a final revaluation of the entire project approach and results. We reflected on the challenges faced, lessons learned, and potential areas for future improvement. This critical step ensured a thorough understanding of our project's strengths and areas for enhancement.



5.3.2 Algorithmic Approaches Used (Mention algorithms, pseudocodes with explanation)

Lift Management Systems employ a variety of algorithms and approaches to efficiently control elevator operations and enhance user experience. The specific algorithms used can vary based on the manufacturer, system design, and the unique requirements of a building. Here are some common algorithms and approaches employed by Lift Management Systems:

First Come, First Served (FCFS):

Description: Elevators serve passengers in the order they arrive at the lobby.
Use Case: Simple and easy to implement, but may lead to inefficient use of elevator capacity and longer wait times.

Minimum Distance Algorithm:

Description: Prioritizes elevator assignments based on minimizing the travel distance to the destination floor.
Use Case: Optimal for scenarios where reducing the physical travel distance is a priority, contributing to energy efficiency and quicker passenger transport.

Minimum Waiting Time Algorithm:

Up-Peak and Down-Peak Modes:

Description: Prioritizes the direction of travel based on the time of day.

Use Case: During up-peak, elevators primarily go upwards to accommodate people arriving at the building. During down-peak, the focus is on bringing people down.

Predictive Dispatching:

Description: Uses historical and real-time data to predict passenger traffic patterns.

Use Case: Proactively dispatches elevators to where they are likely to be needed next, optimizing response times.

Learning Algorithms:

Description: Adapts to passenger traffic patterns over time using machine learning.

Use Case: Adjusts dispatching strategies based on observed patterns, improving efficiency.

Dynamic Reassignment:

Description: Dynamically reassigns elevator cars to different zones based on real-time conditions.

Use Case: Optimizes response to changing traffic patterns and demand.

Ant Colony Optimization (ACO):

Description: Inspired by the behavior of ants, optimizes routing and dispatching.

Use Case: Simulates the way ants find the shortest path, improving overall system efficiency.

Genetic Algorithms:

Description: Uses concepts from evolutionary biology to find optimal dispatching strategies.

Use Case: Evolves over time to adapt to changing conditions and optimize performance.

Fuzzy Logic:

Description: Accounts for uncertainties and imprecise information in dispatching decisions.

Use Case: Enhances decision-making by considering varying degrees of certainty.

These algorithms and approaches can be used individually or in combination, and their effectiveness depends on factors such as building layout, traffic patterns, and user preferences. Modern Lift Management Systems often employ a blend of these strategies to provide adaptive and efficient vertical transportation.

5.3.3 Project Deployment (Can be explained using Component and Deployment Diagrams)

In the context of the Lift Management System project, project deployment involves both the implementation of lift optimization algorithms on a collaborative server and the development of hardware to execute our lift allocation system. Here's an elaboration on each aspect:

Collaborative Server for Algorithm Deployment:

Description: The lift optimization algorithms designed for the project are deployed on a collaborative server, such as Google Colab or a similar platform. This server allows for efficient collaboration among team members and provides a centralized environment for algorithm development, testing, and refinement.

Benefits: Collaborative servers enable real-time collaboration, version control, and the utilization of shared computational resources. Algorithms can be developed and refined collectively, ensuring a seamless integration of ideas and expertise.

Algorithm Development and Optimization:

Description: The lift optimization algorithms are meticulously developed and optimized on the collaborative server. These algorithms aim to enhance elevator system efficiency, reduce waiting times, and improve overall user experience. Various optimization techniques, including machine learning and heuristic approaches, are explored and fine-tuned within this collaborative environment.

Benefits: Centralized algorithm development ensures a unified and coherent approach. Team members can contribute expertise from diverse domains, fostering innovation and comprehensive problem-solving.

Hardware Implementation for Lift Allocation:

Description: In parallel with algorithm development, hardware is being designed and implemented to execute the lift allocation system in a physical environment. This involves the integration of sensors, actuators, and control systems to facilitate the efficient operation of elevators based on the optimized algorithms developed on the collaborative server.

Benefits: The hardware implementation bridges the gap between theoretical algorithms and real-world application. It allows for the validation of algorithms in a tangible, physical setting and ensures compatibility with existing elevator infrastructure.

Integration of Software and Hardware Components:

Description: The collaborative server serves as a hub for coordinating the integration of software (algorithms) and hardware components. This integration ensures that the lift management system operates seamlessly and efficiently in real-world scenarios, taking into account the complexities of a dynamic and user-centric environment.

Benefits: By integrating software and hardware components, the project aims to create a holistic lift management solution that is both intelligent in its algorithmic approach and practical in its implementation.

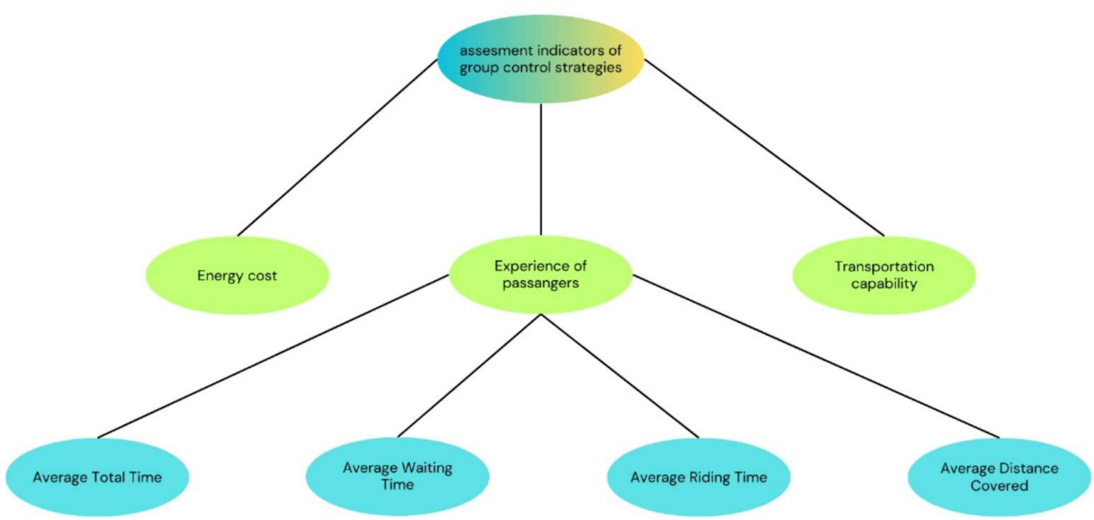
Testing and Iterative Refinement:

Description: The deployed algorithms and hardware undergo rigorous testing to evaluate their performance under various conditions. Continuous feedback and iterative refinement take place based on the results obtained from testing, ensuring that the lift management system continually evolves and adapts to dynamic scenarios.

Benefits: Testing and refinement are crucial for optimizing the system's performance, addressing any unforeseen challenges, and enhancing its overall reliability and efficiency.

By deploying the lift optimization algorithms on a collaborative server and concurrently developing hardware for system implementation, the project achieves a comprehensive and practical solution for elevator management. This approach allows for seamless collaboration, efficient algorithm development, and a tangible implementation that aligns with real-world requirements.

5.3.4 System Screenshots



Assessment result of Mornign Peak mode:

	Algorithms	Average Total Time	Average Waiting Time	Average Riding Time	Average distance covered	Total Stops
0	Shortest Distance	51.0	23.333333	27.666667	46.666667	15
1	Minimum Time	48.5	20.833333	27.666667	46.666667	19

Assessment result of Morning Normal mode:

	Algorithms	Average Total Time	Average Waiting Time	Average Riding Time	Average distance covered	Total Stops
0	Shortest Distance	51.0	23.333333	27.666667	46.666667	15
1	Minimum Time	48.5	20.833333	27.666667	46.666667	19

Assessment result of Lunch mode:

	Algorithms	Average Total Time	Average Waiting Time	Average Riding Time	Average distance covered	Total Stops
0	Shortest Distance	49.171429	9.000000	40.171429	49.428571	95
1	Minimum Time	49.314286	9.142857	40.171429	49.428571	103

Assessment result of Evening mode:

	Algorithms	Average Total Time	Average Waiting Time	Average Riding Time	Average distance covered	Total Stops
0	Shortest Distance	49.523810	8.666667	40.857143	50.000000	54
1	Minimum Time	47.238095	6.380952	40.857143	48.095238	57

Assessment result of After Hours mode:

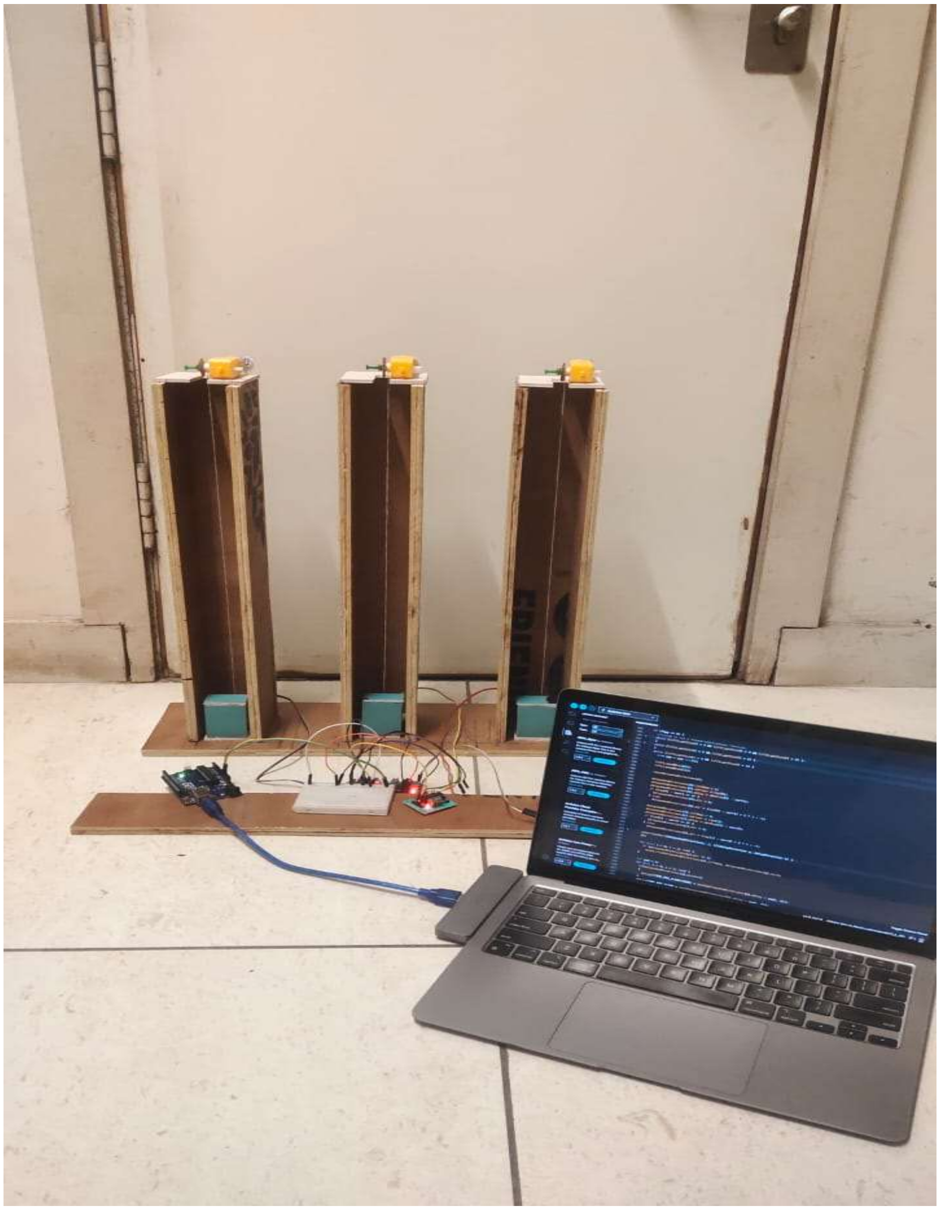
	Algorithms	Average Total Time	Average Waiting Time	Average Riding Time	Average distance covered	Total Stops
0	Shortest Distance	0.0	0.0	0.0	0.0	0
1	Minimum Time	0.0	0.0	0.0	0.0	0

Assessment result of Mornign Peak mode:

	Algorithms	Average Total Time	Average Waiting Time	Average Riding Time	Average distance covered	Total Stops
0	Shortest Distance	51.222222	10.222222	41.0	51.111111	124
1	Minimum Time	49.400000	8.400000	41.0	49.777778	131

'hdgfh'

	Algorithms	Average Total Time	Average Waiting Time	Average Riding Time	Average distance covered	Total Stops
0	Shortest Distance	51.0	23.333333	27.666667	46.666667	15
1	Minimum Time	48.5	20.833333	27.666667	46.666667	19



5.4 Testing Process

This section delineates the comprehensive testing strategy employed to evaluate the efficacy and performance of the project. The testing process encompasses test plans, test cases, and the adopted methodology to ensure the robust functionality of the implemented model.

5.4.1 Test Plan

The test plan was meticulously crafted to closely align with the defined objectives and performance parameters. In the execution phase, the algorithms were run, and the model was trained on Google Colab. The resulting JSON-type output of the lift schedule from the machine learning models was seamlessly integrated into the Arduino system to enable its optimal functionality.

5.4.2 Features to be tested

Software (Machine Learning Part)

The features that need to be tested in the software implementation of the same are:

1. Simulating the Working of an Elevator (Directional Up and Down)
2. Identifying and Visualizing Peak Traffic Hours
3. Predicting Weight Value for Trade-off Between Waiting Time and Distance Traveled
4. Emergency Stop Case
5. Sending Signal to Move to Ground Zero After 5 Minutes of Inactivity
6. Handling Multiple Requests
7. Model gives output in a JSON-compatible format

Hardware (Arduino)

The features that need to be tested in the hardware implementation of the same are:

1. Input from the serial monitor
2. Execution of requests in order
3. Appropriate window of waiting time so that people can get on and off.
4. Proper display of motion and current floors while processing the requests.

5.4.3 Test Strategy

S.No.	Environment Name	Description	Network	Usage
1	Development	Local development environment for algorithm testing and refinement.	Isolated	Algorithm development and testing.
2	Simulation	Simulated model environment for algorithm validation and performance assessment.	Virtual	Simulating elevator group scenarios for optimization testing.
3	Prototype Integration	Integration of algorithms into a prototype system using Arduino.	Local	Testing algorithm functionality in a hardware-integrated environment.
4	Staging	Pre-production environment mirroring the actual building layout for realistic scenario testing.	Local Network	Assessing algorithm performance in conditions similar to the target deployment.

5.4.4 Test Techniques

1. **Unit Testing**: This technique involves testing individual units or components of the software in isolation. It is typically performed by developers and focuses on verifying that each unit of code functions as intended.
2. **Integration Testing**: Integration testing involves testing the interactions between different units or components of the software to ensure that they work together as expected. It can be performed at different levels, such as module integration, system integration, and acceptance testing.
3. **System Testing**: System testing involves testing the entire software system as a whole. It verifies that the integrated software meets the specified requirements and functions correctly in its intended environment.
4. **Performance Testing**: Performance testing involves testing the software's performance under various conditions, such as load, stress, and scalability, to ensure that it meets performance requirements.
5. **Security Testing**: Security testing is performed to identify vulnerabilities in the software and ensure that it is resistant to unauthorized access, data breaches, and other security threats.
6. **Automated Testing**: Automated testing involves using tools and scripts to automate the execution of tests, which can help improve efficiency and repeatability of testing processes.

5.4.5 Test Cases

Software (Machine Learning Part)

Test Case	Description	Expected Output	Pass/Fail/ Partial Pass
1	The algorithm should simulate the working of an elevator. Directional up and down.	Elevator moves up and down based on requests.	**Pass**
2	The algorithm should correctly identify and visualize the peak traffic hours in the dynamic traffic pattern.	The Peak traffic hours are identified, and a visualization shows the patterns. The algorithm should correctly identify and visualize the peak traffic hours in the dynamic traffic pattern.	**Pass**

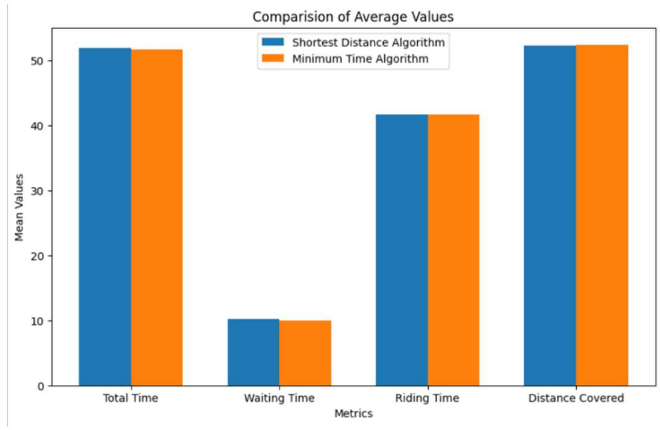
3	The model should be able to predict a weight value such that a trade-off between waiting time and distance traveled is created.	Balanced trade-off achieved between waiting time and distance traveled based on weight value predictions.	**Pass**
4	The algorithm should send a signal to the lift to move to its ground zero after 5 minutes of inactivity.	Lift receives a signal to move to ground zero after 5 minutes of inactivity.	**Pass**
5	Emergency stop case where the lift stops if an emergency button is pressed at that floor, and on restart goes to ground zero.	Elevator stops on emergency press, restarts, and goes to ground zero of inactivity.	**Pass**
6	The algorithm should be able to handle multiple requests of the lift.	Multiple requests are efficiently handled and prioritized.	**Pass**
7	The model gives output in a JSON-compatible format that can be integrated/sent to the Arduino (for our project simulation) or Coral module (in actual implementation).	Output is in JSON format compatible with integration and can be sent to the Arduino or Coral module.	**Pass**

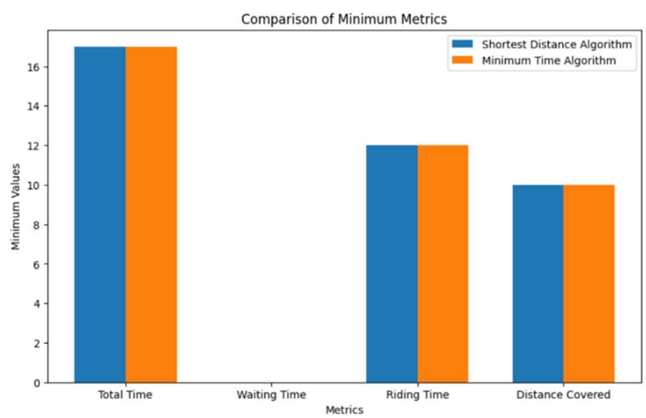
Hardware (Arduino)

Test Case	Description	Expected Output	Pass/Fail/ Partial Pass
1.	The input JSON from the serial monitor should be asked for everytime, after execution of a schedule and no functioning should happen until a new schedule is received as input in the form of a valid JSON Object (i.e. a JSON having atleast three key, value pair as shown: {“lift1”:[],”lift2”:[],”lift3”:[]}	Actions of moving the motor only starts when we receive a valid JSON Object else if there is an input JSON is not valid an error is thrown.	**Pass**
2.	The order of execution of the received floors to stop on is done in the reverse order of execution as mentioned.	The motor moves according to the order of execution moving up and down depending on the current floor it was stationed on.	**Pass**
3.	While the lift is moving up and down we also try to simulate it’s standard stopping action at a particular floor without any human intervention or interrupts.	The motor would stop for a definite time on reaching each floor it was intended to reach on.	**Pass**
4.	Display of the movement and the information regarding the update of the floors of the lifts should be visible on the serial monitor as it happens.	There is display of current floors after every updation and for the movement and stopping of lifts, along with outputs stating opening and closing of gates.	**Pass**

5.5 Results and Discussions (Visualization of results using graph plots and Comparison with related state of the art work)

To enhance user experience, the metric of time of travel is utilized. Time of travel comprises ride time, wait time, and additional time, influenced by the number of stops the elevator makes and the duration required for the opening and closing of doors. Through the calculation of metrics for average and minimum values of these parameters, the following comparisons were derived

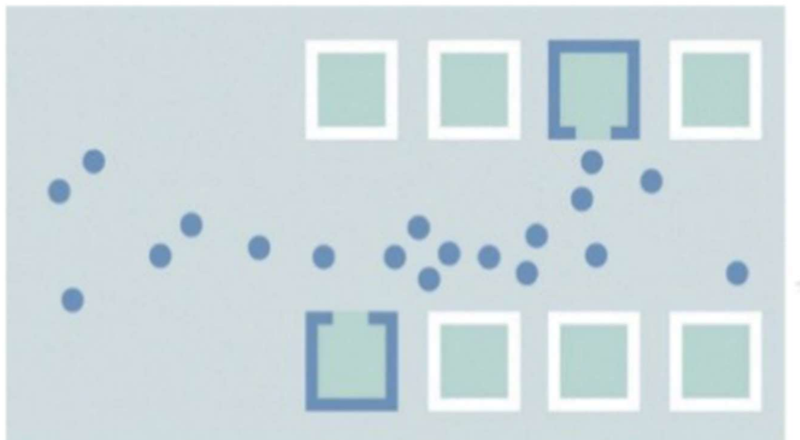




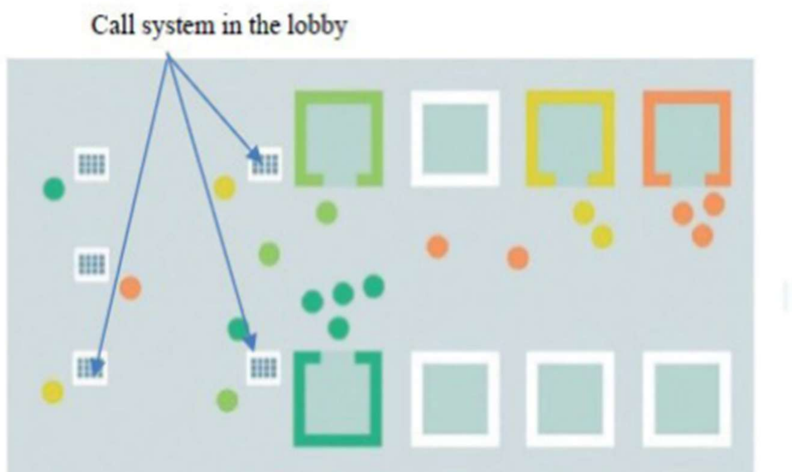
We formulated an algorithm to optimize elevator operations, allowing for the assignment of lifts based on minimum time, minimum distance, or a combination of both. The techniques that exhibited notable efficacy encompassed:

Zone Control: This approach involves segregating the building according to a specific metric. The effectiveness of this method is contingent upon the building's layout and patterns. The zoning can be established based on a simple floor-to-elevator mapping or take into account factors such as the number of stops, waiting times, or occupancy.

Predictive Dispatching: In contrast to traditional elevator dispatching systems that react to immediate requests, predictive dispatching aims to proactively address elevator demand by forecasting future requests and allocating elevators accordingly. A significant advantage of predictive dispatching lies in its capacity to enhance passenger experience, minimizing wait times and improving overall system efficiency. By analyzing historical data, user patterns, and relevant factors, predictive dispatching algorithms can anticipate peak hours and strategically distribute elevator resources. This ensures a smoother and more responsive transportation experience for building occupants.



Conventional dispatching system



Destination dispatching system

Ant Colony Optimization (ACO): ACO is a metaheuristic algorithm inspired by the foraging behavior of ants. In the context of elevator optimization, ACO can be applied to enhance decision-making processes related to elevator movements. Ants deposit pheromones along their paths, and other ants use these pheromone trails to make decisions. Similarly, in elevator optimization, artificial "ants" can represent elevator cars, and the pheromone trails signify the desirability of a particular route.

Ultimately after careful analysis of algorithms we can develop a tradeoff to achieve our desired result.

5.6 Inferences Drawn

The following insights and conclusions were derived from the study:

1. **Identification of Peak Traffic Patterns**: Distinct traffic patterns were observed during different times of the day. Notably, mornings exhibited a majority of traffic originating from the ground floor, while evenings saw an influx of traffic heading towards the ground floor. Additionally, there was a surge in passenger numbers during the peak lunchtime hours.

2. **Comparative Analysis of Metrics**: A comparison was conducted between metrics involving distances and minimum time, facilitating the visualization of patterns. This analysis aimed to establish a trade-off between the two metrics, informing the development of strategies that optimize elevator operations.

3. **Evaluation of Elevator Dispatching Algorithms**: Various algorithms for optimizing elevator dispatching, including zoning, predictive dispatching, and ant colony optimization, were explored and analyzed. Results indicated that these algorithms yielded promising outcomes in terms of system efficiency and user experience enhancement.

4. **Parameter Utilization for Trade-off Creation**: The acquired insights and learned parameters were employed to establish a trade-off between minimizing travel distance and minimizing travel time. This strategic approach not only enhances user experience but also contributes to improved energy efficiency within the elevator system.

5.7 Validation of Objectives

Sr. No.	Objectives	Status
1.	To understand the existing elevator group structure.	Successful
2.	To explore the best machine learning and deep models to optimize elevator group performance.	Successful
3.	To increase the system's efficiency by developing algorithms responding to occupancy levels, user inputs, and traffic patterns routinely used in elevator lobbies.	Successful
4.	To reduce the system's power consumption by incorporating various optimization algorithms.	Successful

6. CONCLUSION AND FUTURE DIRECTIONS

6.1 Conclusions

The implemented algorithms intelligently respond to occupancy levels, user inputs, and traffic patterns, optimizing elevator scheduling and enhancing energy efficiency. Integrating various elevator models to better the accuracy and prediction capability of the final model. The hardware is also made to simulate an elevator group with 3 elevators using plywood based shafts for demonstration purposes. All in all the set objectives in time will be fulfilled with good accuracy and efficiency. The system's scalability and potential for future enhancements promise to usher in new possibilities, making vertical transportation an even more efficient and intelligent aspect of modern building management. The effort of all the team members to work together to achieve together is commendable.

6.2 Environmental/Economic/ Social Benefits

Environmental: The enhancement of the elevators aims to minimize the carbon footprints generated by the elevators in a group by optimizing the performance using Machine Learning and Artificial Intelligence.

Social: This enhancement of the elevators aims to enhance the user experience by minimizing overall waiting and ride time at peak hours.

Economic: The AI-based optimization of the elevators aims to minimize the overall consumption of energy, helping ease of total operational expenses to the company.

The Elevator Group Management System has indisputable benefits for managing the urban infrastructure of a city. It creates a more efficient and smoother operating system for elevators, saving time and energy.

6.3 Reflections

Throughout the course of the lift management system project, our team has gained invaluable insights into the intricate dynamics of designing and implementing efficient elevator algorithms. One of the primary reflections is the critical balance between algorithmic sophistication and user-centric functionality. While advanced algorithms contribute to optimize system performance, it is imperative to continually prioritize user experience to ensure satisfaction and acceptance. We've learned that real-world challenges, such as peak demand scenarios and unexpected user behaviors, necessitate adaptive and dynamic algorithmic strategies. Additionally, the importance of robust data collection, cleaning, and normalization processes cannot be overstated, as the quality of input data profoundly influences algorithmic outcomes. Collaborating on this project has not only expanded our technical understanding of lift management systems but has also underscored the significance of interdisciplinary collaboration, iterative refinement, and user feedback in the successful implementation of smart and responsive vertical transportation solutions. Looking forward, we recognize the ever-evolving nature of such systems, prompting a commitment to continuous learning and adaptation as we strive to contribute to advancements in elevator technology. The team also learnt and understood the know how about the integration and working of the hardware alongside software.

6.4 Future Work

While the system has achieved significant milestones, there are exciting avenues for enhancements and expansions to further elevate the system's capabilities and impact. The following outlines the future work plan for the LMS:

Advanced Predictive Maintenance:

Develop more advanced predictive maintenance capabilities by incorporating additional sensors and data sources. This can lead to early detection of potential issues and proactive maintenance measures.

Energy Consumption Analytics:

Develop in-depth energy consumption analytics and reporting features. Provide building administrators with detailed insights into energy usage patterns, allowing for informed decisions on energy-saving strategies.

Smart Building Integration:

Explore integration with emerging smart building technologies to create a holistic building management solution. Integrating environmental control, lighting, and security systems can provide a seamless and comprehensive building experience.

User Feedback Mechanism:

Implement a user feedback mechanism within the LMS interfaces. Collect user feedback on elevator experiences and use this information to fine-tune algorithms and enhance user satisfaction.

Accessibility and Inclusivity Features:

Introduce accessibility features to cater to users with diverse needs, such as visual or mobility impairments. Ensure that the LMS provides a seamless experience for all occupants.

Federated Learning to increase security:

Owing to data security even with the lift usage data, techniques like uncentralised modeling and federated could be implemented so that the real data is masked at source and not available to the hacker in case of a breach of security.

Authorisation features like biometrics and RFID cards:

Enhance the security and access control of the EGMS by incorporating advanced authorization features such as biometrics and RFID cards. By integrating these authorizationg fingerprint or facial recognition, adds an additional layer of security, ensuring that only authorized individuals can access the elevators. RFID cards provide a convenient and secure method for authentication, offering occupants a choice in how they access the elevator system. By integrating these authorization features, the EGMS not only enhances security but also provides a flexible and user-centric approach to access control.

7. PROJECT METRICS

7.1 Challenges Faced

The team faced a lot of challenges during the making of this project which include both emotional and technical challenges.

The major challenge that we faced was confidentiality of current lift algorithms and the dataset availability of the same; because the tech giants are reluctant to share the information due to confidentiality compliances.

Another challenge we faced was finding the most appropriate algorithm which could predict near perfect results and is an improvement on the trade-off between minimum time and energy efficiency.

Challenges in coding and implementing the hardware were no less; the type of motor to be used and the reading of JSON and time specific execution of motors were not the only issues; the team faced challenges while building the lift shafts and hammering of the plywoods.

Although we faced these challenges, the team bonded and grew together, completing the project in the stipulated time limit.

7.2 Relevant Subjects

Subject Code	**Subject Name**	**Description**
UTA009	Computer Programming II	Basics of C++ helped to understand the basics of JavaScript and Node.js
UCS520	Computer Networks	The basics of networking helped in understanding and troubleshooting the problems with Firebase connection and Hosting the database.
UCS310	Database Management System	The basics of SQL were used to build upon the NoSQL database of Firebase.
UCS407	Inventions and Innovations in Computing	During the assignments and the reading of the applications in demand of the day, team members decided to work on the domain of this application.
UCS503	Software Engineering	All the UML Diagrams and other design specifications were taught in this course.
UCS523	Computer and Network Security	This course enlightened about the security paradigms and the use of SSL certificates that have been done in the Mobile App.

UCS641	Cloud Computing	Working on Amazon Web Services as part of the course and that was used as the development as well as deployment platform for the Mobile App.
UML501	Machine Learning	While working on numerous optimal approaches to figure out the best model to suit our pre-conditions and produce the desired result we have used approaches from the learnings of the course Machine Learning.
UCS704	Embedded System	While coding the Arduino concepts and logic from this course played a crucial role in circuit design and running of the motor.

7.3 Interdisciplinary Knowledge Sharing

The discussion about the utility and feasibility of the idea were conducted between the group members during the project. Knowledge sharing between human psychology and the thought of making our idea creative and practical helped us in developing our model. Ancient rules of stoic along with the principles, helped us stick together as a team. The knowledge sharing between Machine Learning, usage of lifts and observation skills helped us to make our model a lot better. The joint strides in embedded systems, database and networking helped bring life to our model, and hence because of this, the problem of performance bottleneck was solved. Since the project was huge and required a lot of brainstorming, various team members being not so proficient in a few technologies, took a while to bridge the barrier between the people being familiar and proficient in it.

7.4 Peer Assessment Matrix

Table 7.2 represents the Peer Assessment Matrix where the members have evaluated our teammates from 1 (minimum) to 5 (maximum).

Evaluation of →/ Evaluated by ↓	CHAHAT JONEJA	JAHNVI GANGWAR	MUKUL SINGHAL	SHAMAYLA JINDAL	VEER DAKSH AGARWAL
CHAHAT JONEJA	5	5	5	5	5
JAHNVI GANGWAR	5	5	5	5	5
MUKUL SINGHAL	5	5	5	5	5
SHAMAYLA JINDAL	5	5	5	5	5
VEER DAKSH AGARWAL	5	5	5	5	5

Table 7.2: Peer Assessment Matrix

7.5 Role Playing and Work Schedule

Jahnvi Gangwar:

- Devised an algorithm based on insights from research papers and developed Python models for implementation.
- Worked on forming dataset for the model
- Participated in implementing the hardware structure and assembly of project
- Conducted thorough online research, contributing valuable insights to the project.
- Actively participated in documentation tasks and ensured the availability of necessary materials.
- Contributed to testing activities, ensuring the quality and reliability of the ML algorithms.
- Collaborated with team members in deciding project objectives, ideation, and methodology and facilitated effective communication between the mentor and the team.

Mukul Singhal:

- Developed the Arduino Uno code for the project.
- Played a key role in implementing the hardware structure and assembly of project
- Conducted thorough online research, contributing valuable insights to the project.
- Actively participated in documentation tasks and ensured the availability of necessary materials.
- Contributed to testing activities, ensuring the functionality of the Arduino code.
- Collaborated with team members in deciding project objectives, ideation, and methodology.
- Facilitated effective communication between the mentor and the team.

Veer Daksh Agarwal:

- Devised an algorithm based on insights from research papers and developed Python models for implementation.
- Participated in implementing the hardware structure and assembly of project
- Conducted thorough online research, contributing valuable insights to the project.
- Actively participated in documentation tasks and ensured the availability of necessary materials.
- Contributed to testing activities, ensuring the quality and reliability of the ML algorithms.
- Collaborated with team members in deciding project objectives, ideation, and methodology.
- Facilitated effective communication between the mentor and the team.

Shamayla Jindal:

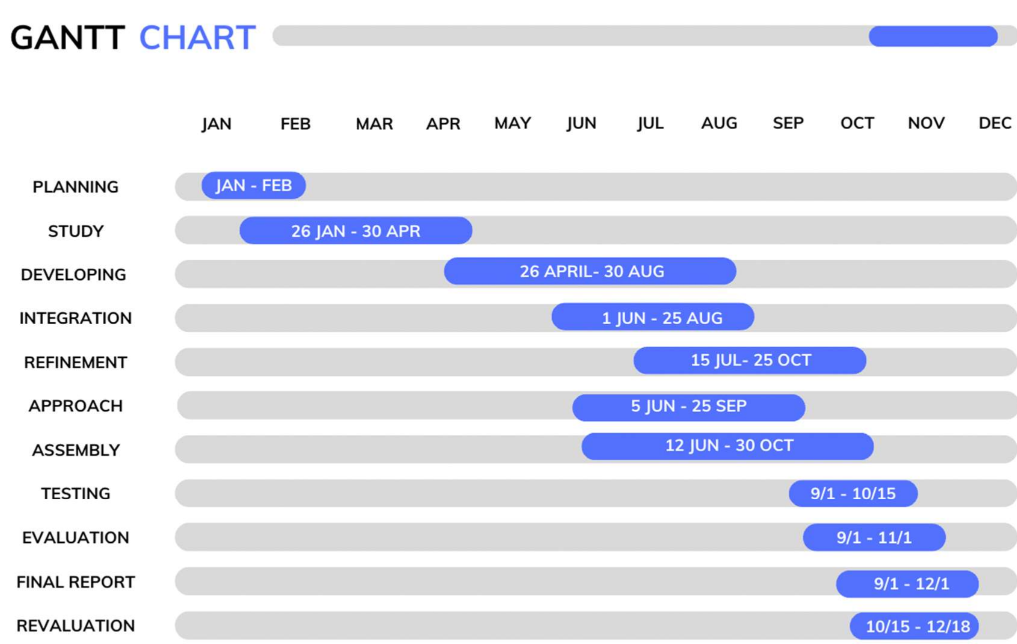
- Conducted thorough online research, contributing valuable insights to the project.
- Created UML Diagrams
- Actively participated in documentation tasks and ensured the availability of necessary materials.
- Contributed to Testing Activities, ensuring the effectiveness of implemented solutions.
- Collaborated with team members in deciding project objectives, ideation, and methodology.
- Ensured proper coordination among team members for seamless project execution.

Chahat Joneja:

- Played a key role in developing UML diagrams for a clear visual representation of project structures.
- Conducted thorough online research, contributing valuable insights to the project.
- Actively participated in documentation tasks and ensured the availability of necessary materials.
- Contributed to testing activities, ensuring the effectiveness of implemented solutions.
- Collaborated with team members in deciding project objectives, ideation, and methodology.
- Ensured proper coordination among team members for seamless project execution.

Work Schedule

1. Planning: Identification Formulation and Planning of project Plan
2. Study: Study of Technologies Required
3. Developing: Developing Algorithms
4. Integration
5. Refinement
6. Approach (Hardware implementation)
7. Assembly: Hardware Assembly
8. Testing
9. Evaluation: Results Evaluation
10. Final report
11. Revaluation



7.6 Student Outcomes Description and Performance Indicators (A-K Mapping)

	Description	Outcome
A1	Applying Mathematical concepts to obtain analytical and numerical solutions.	Used concepts like convolution, hyperparameter optimization, complexity analysis for body pose recognition and wrapping respectively.
A2	Applying basic principles of science towards solving engineering problems.	Machine Learning itself incorporates applied statistics and mathematical models
A3	Applying basics of material engineering	Used concepts of torque stability and durability to understand the structural constraints, present in the simulation.
B1	Identify the constraints, assumptions and models for the problems.	Given the unavailability of either the dataset or the algorithms available; identification of constraints was done with limited available data and observations made during analysis phase.
B2	Use appropriate methods, tools and techniques for data collection.	We used the techniques and tools that in spite of limited computing power and scope of human error would help us in achieving the desired results.
C1	Design software system to address desired needs in different problem domain..	Our system was made to streamline collaboration between various entities with special attention towards user experience.
C2	Design the hardware keeping in mind the constraints pointed out in the Analysis phase.	The hardware is a simulation of 3 lifts controlled by DC motors using Arduino Uno R3 along with H-Bridge ICs.
D1	Fulfil assigned responsibility in multidisciplinary teams.	The whole project was divided among five team members to make effective use of the shared knowledge.
D2	Can play different roles as a team player.	Each member was easily able to switch from one responsibility to another responsibility to the need. Documentation and development responsibilities were shared among all the members.

E1	Identify engineering problems.	As technological advancements unfold in the future the models would need updation as well.
E2	Identifying structural problems.	If the floors for food court and office blocks are changed the model would need to be tweaked to suit the changes in the zones.
F1	Showcase professional responsibility while interacting with peers and professional communities.	All of the members were punctual in tending the group meetings to discuss the upcoming responsibilities. The team was regular at arriving at the evaluation destination for panel and mentor evaluation as well.
G1	Produce a variety of documents such as laboratory or project reports using appropriate formats.	The team has been successful in preparing and presenting the project documentation in appropriate format.
G2	Deliver well-organized and effective oral presentation.	The team has been able to effectively communicate the idea behind the project and its implementation details to the mentor and the evaluation panel.
H1	Reflection about the best suited approach to implement the hardware.	Numerous approaches were used to replicate pseudo parallel behavious of lift movement.
I1	Able to explore and utilize resources to enhance self-learning.	The team relied on different research papers and websites like Medium, Stack Overflow, YouTube to help with the implementation and theoretical concepts of the project.
J1	Comprehend the importance of contemporary issues.	Technical expertise in general public is relatively less therefore the system has been designed to be high generic and simple.
K1	Write code in different programming languages and software tools necessary for computer engineering domain	Various programming languages were used for development of the project such as Python, C++ etc.
K2	Apply different data structures and algorithmic techniques.	To advance our model boundaries, data structures and algorithms were utilized.

7.7 Brief Analytical Assessment

In a nutshell, the project proved to be a really great learning experience for the group. The project involved going out of the way from the course syllabus and techniques. We had a very good experience with prototyping and documenting a product along with development of team skills which is crucial for state-of-the-art projects. It was good to see how product development actually takes place and how we could learn to work in a team, cover each other's work and at the end, come out with a working product.

Q1: What sources of information did your team explore to arrive at the list of possible Project Problems?

Answer: The team first went through the previous year's projects made by our seniors to understand the level of complexity required in the project as well as so as not to get to a similar idea. We surveyed several resources that included Google searches, projects on Adafruit.com, YouTube, and many blogs.Thirdly, the group went through the Course Inventions and Innovations in Computing to understand the department’s inclinations. Lastly, the team had a brainstorming session with our Mentor to zero down on the idea of building upon the concepts of smart lifts as a subsection of smart cities and building a helping environment with technology.

Q2. What analytical, computational, and/or experimental methods did your project team use to obtain solution to the problems in the project?

Answers: Understanding and visualizing the time-series data of lift usage to find the peak hours of usage and then process the same using algorithms like Ant-colony optimisation, predictive dispatching along with hyperparameter optimization techniques. It was a cumbersome task to make sure it is time and cost efficient.

Q3: Did the project demand demonstration of knowledge of fundamentals, scientific and/or engineering principles? If yes, how did you apply?

Answer: Certainly, the Lift Management System project demanded a demonstration of knowledge across various engineering and scientific principles. The application of electrical engineering fundamentals was evident in designing reliable and safe electrical components.The implementation of AI and algorithms showcased proficiency in machine learning and reinforcement learning for intelligent system behavior. Data science techniques were applied for data cleaning and normalization. Consideration of energy efficiency principles contributed to optimizing the system's environmental impact. Software Engineering techniques were also used to handle the documentation part.

Q4: How did your team share responsibility and communicate the information of the schedule with others in the team to coordinate design and manufacturing dependencies?

Answer: Most of the work was done sitting together either in the GD room or in activity space 1. Members maintained a fixed time routine for work every day for the last two-three months. In this manner, the team was able to coordinate and share information. The responsibility was divided on a module basis. Online meetings were also held during vacations along with sharing of documents over whatsapp and a combined google document helped in simultaneous working on the same thing.

Q5: What resources did you use to learn new materials not taught in class for the course of the project?

Answer: Throughout the Lift Management System project, we actively sought additional resources beyond the classroom:

<u>Research Papers and Journals</u>: Explored academic papers on elevator system optimization, AI applications, and smart building technologies.

<u>Online Courses</u>: Enrolled in courses covering reinforcement learning, machine learning, and advanced algorithmic approaches.

<u>Textbooks and References</u>: Consulted textbooks on electrical engineering, AI, and data science to reinforce foundational knowledge.

<u>Youtube Videos</u>: Various youtube tutorials were seen in order to implement the hardware seamlessly.

By diversifying our resources, we broadened our knowledge and overcame challenges beyond the classroom curriculum, contributing to the project's success.

Q6: Does the project make you appreciate the need to solve problems in real life using engineering and could the project development make you proficient with software development tools and the environment?

Answer: A real-life problem is addressed by our project by using engineering skills. While working on this project, we have acquired various skills and given us the motivation to solve real-world problems in diverse fields. We have learned about various technologies during the making of this project like Machine Learning, ArduinoJson implementation and usage and various other Python and Arduino libraries. Thus, working on these technologies helped us in improving our skills in different technological fields.

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