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Dynamic Dispatching of Elevators in Elevator Group Control System: Research and Survey

Malan D. Sale, V. Chandra Prakash

Abstract*: With an increase in the population and demand for elevators in high-rise buildings, there is a need for installing more number of elevators to transport passengers efficiently. In tall buildings, Elevator Group Control System (EGCS) is the system for managing vertical transportation facility. The paper presents a survey of different techniques used to schedule and dispatch elevators in EGCS. The research study focuses on the dynamic scheduling of elevators for all up and down landing calls that aims to overcome the limitations and weaknesses of the existing works. The main aim of the research work is to reduce the waiting time of passengers for a car call on a specific floor and save power consumption of the elevators or lifts. Fuzzy algorithms, neural network algorithms, and genetic algorithms are the primary methods used to dispatch elevators in the control system. The study compares experimental results generated by various methods.

***Index Terms*: EGCS, Elevators, up-peak traffic, down-peak traffic**

I. INTRODUCTION

Installation of elevators in tall buildings is essential to provide transportation services to passengers. Use of elevators leads to reduce the human energy and valuable time to move up & down through stairs.

A massive amount of tall buildings with a growing number of floors constructed in recent years, the crucial issue in an elevator is to give better transportation facility.

People prefer to lift instead of stairs to go to the top floors of the building. In the traditional elevator control system with only one working lift, people face many problems like long waiting time for the lift and long journey time as multiple passengers use a single lift. The use of multiple lifts in tall buildings to provide vertical transportation facility solves this problem. Elevator Group Control System (EGCS) works as the manager for vertical transportation facility in tall buildings. EGCS effectively manages multiple elevators based on various parameters such as the waiting time of passengers, the percentage of waiting and up-floor traffic & down-floor traffic. The first activity of the EGCS is to answer all passenger calls, which will improve the overall performance of the group of elevators and not of few elevators in the group.

The principal intention of elevator group control is to give the functional administration of a group of elevators, by recruiting cars to meet landing calls. The act of hiring elevator is nothing but the assignment control of landing calls. The selection process concentrates on the average lift-response time, average passenger waiting time and some other control indices. The random change in passenger's arrival and request need to recognize by EGCS. Neural network algorithms used in EGCS to build more intelligent and optimized system.

This paper presents an in-depth literature study of different techniques used to enhance the efficiency of EGCS. Artificial intelligence (AI), Neural Networks (NNs), Genetic algorithms (GAs), fuzzy-based systems are some of the techniques used to optimize the elevator functioning.

The paper organized as follows: section II gives some literature reviews of the research work done in the field of EGCS. Section III gives categorization and comparison of algorithms. Section IV gives some experimental results from the literature. Finally, Section V concludes the paper.

II. LITERATURE REVIEW

Different studies focused on different algorithms to provide an optimized solution for the scheduling of elevators in EGCS. All studies give their best solutions with some merits and demerits. The paper focuses on the comparison of various algorithms. The article categorizes references in different categories like fuzzy algorithms, zoning algorithms, Artificial intelligence algorithms, neural networks, and genetic algorithms. Many research studies focus on genetic algorithms to allocate an elevator. Some studies use zoning algorithms to assign car as a response to the landing calls. However, the zoning method is not so efficient for dynamic allocation. Other techniques like neural networks need proper employee training before its use. The used procedures are very complicated to understand and implement and do not give the desirable/expected results in various conditions. The techniques such as ant colony optimization give good solutions as compared to others but are challenging to implement, when combining with other methods like neural networks and fuzzy logic. Fuzzy algorithms with DSP board are used to allocate elevators in EGCS.

The study of J. Fernandez and P. Cortés [1] gives the first dynamic solution to the landing calls. The work is under different considerations like average waiting time, average response time by the lift, and traffic consideration. The study focused on the fuzzy logic algorithm to find the solution. The traffic flow of the passengers at a particular time not considered in the study. The study considers only one call button on each floor.

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***Correspondence Author(s)**
Malan D. Sale, Research Scholar, Dept. of Computer Science & Engineering, K.L.E.F., Vaddeswaram, Andhra Pradesh, India.
Dr. V. Chandra Prakash, Professor, Dept. of Computer Science & Engineering, K.L.E.F., Vaddeswaram, Andhra Pradesh, India.

When the call comes from a specific floor, the EGCS allocates a car to the floor by finding a minimum waiting call.

The study of Fu, Lijun, and Tiegang Hao [2] focus on analysis and simulation for the passenger flow in EGCS using MATLAB. The model provides a foundation for the research, as it handles passenger flow data. The source and destination floors of the traveling passengers found through Monte-Carlo sampling. This information is useful for other researchers working on EGCS. A study focuses on the comparison of the Fuzzy control algorithm with the different algorithms.

The research of Qiu, Jian, Dong, and ZhaoYuan Jiang [3] focuses on simulation built in MATLAB using Fuzzy control algorithm. The Fuzzy Control Algorithm takes into account the average waiting time AWT, the average reaching time ART, the long waiting time probability LWP, and power consumption RPC. With these parameters, the weighted average function S is-

Si = Wait time 1 AWTi + Wait time 2 LWPi + Wait time 3 RPCi + Wait time 4 ARTi (1)

The different fuzzy variables used as input to systems are DWT (waiting time of the passenger), max DWT (the maximum of DWT), NRC (next response call), LCR (concentration ratio calculated for new incoming call location) and UR (utilization ratio calculated for the up direction and the down direction elevator car). The five fuzzy variables used in an algorithm are 1] very large (VL) 2] large (L) 3] middle (M) 4] small (S) and 5] very small (VS).

A new method for scheduling of the elevators in EGCS presented by Yang, Suying, Jianzhe Tai and Cheng Shao [4] uses destination floor information. The system uses a single input method instead of two inputs, one for hall call request and other for destination floor choice. The study focuses on the dynamic partitioning method for up-peak traffic mode only. Based on passenger distribution and traffic flow, floors are divided into regions dynamically. The system uses a Fuzzy Neural Network in the dynamic programming algorithm. The system collects information about the source, destination floor and the count of passengers wishing to go to the same floor. The system allocates ID's to elevators to decide the route and gives notification to the passengers about the assigned elevator.

The steps used to schedule EGCS by using Directed Flow Graph (DFG) are

1) When a destination call from xth floor to yth floor is registered, the system collects related information and stores in the database.

2) Assign elevator to the hall call application i, store in the message queue.

3) Using the optimal policy for the hall call of destination floor y, select the elevator z and go to the source floor x. Wait until the next registration.

4) When elevator z reach to the x^{th} floor, the DFG subsystem allocates the elevator z for the current request. Then it executes the dispatching operation.

5) When elevator z come at the y^{th} floor, the DFG subsystem modifies the scheduling status of elevator z and frees the memory allocated for the application i.

Fernandez, Cortes, Guadix, and Munuzuri [5] proposed a dynamic fuzzy logic EGCS to dispatch landing calls for optimizing power consumption, especially during inter-floor traffic. Dispatching criteria includes absolute and relative energy evaluation along with adjoining of landing calls evaluation. Simulation results show desirable performance on different demands of inter-floor traffic.

The study of Liting, Cao, Zhang Zhaoli, and Hou Jue, [6] focus on Artificial Intelligent technology to optimize the dynamic dispatching of the elevator system. Simulation done is in MATLAB using ANN, expert system, and the fuzzy system control theory to optimize the elevators dispatching operation. There are two modules in the system, the first is the traffic identification module to find traffic patterns and second is the current traffic flow. The second module focused on a car dispatching operation. It calculates the parameters required for car dispatching, the coefficients of power and the best dispatching technique.

The research of Sun, Jin, Qian-Chuan Zhao and Peter B. Luh [7] presents a new scheduling algorithm for the effective use of advance traffic information. As these methods, take more CPU time further improvement needs in the research to reduce CPU time. The study concentrates on advance traffic information with Door action control scheme to improve elevator systems, which solves the scheduling problem in the EGCS. Hybrid nested partitions with the genetic algorithm used for the passenger-to-car assignment task. The study introduces a new technique where the passengers can make the entry of their destinations in the destination entry system through keyboards before they enter into the lifts. In the proposed systems, the system knows passenger arrival times, source floor, and the destination floor in advance before taking decisions. The proposed system utilizes advance information collected before the passenger is traveling. It is a challenging issue to develop such a system, which can effectively use advance information.

The study of Wang, Donghua, and Baofeng Li [8] focuses only on the up-peak traffic mode and provides the optimal strategy of dynamic zoning to the elevators.

Depending on the passenger traveling, traffic mode categories are 1] up-peak traffic 2] down-peak traffic 3] inter-floor traffic and 4] the idle traffic. The study has discussed the dispatching strategy in an up-peak traffic mode only. The study considers two approaches, nearest car NC and Estimate Time of Arrival ETA to optimize the waiting time of the elevator systems.

The study of Cortes, Pablo, et al. [9] proposes a method using Fuzzy Logic (FL) for dynamic identification of peak traffic. Fuzzy Logic needs less input information. FL described in three steps: (i) Fuzzification, (ii) the inference process based on the logic rule and (iii) DeFuzzification. Convert the input values into fuzzy values in the Fuzzification process, reconvert the fuzzy variables and take the desired decision in the deFuzzification process.

Chen, Yuan, Lee, and Wang [10] implemented a fuzzy based EGCS optimization method using a Genetic Algorithm. The study describes the architecture of the proposed method along with the efficiency made at different peak times. The study of Cao, Liting, et al. [11] focuses on the immune system in dynamic zoning. In dynamic zoning, the EGCS collects all request calls of a particular floor, predicts the most favorable traffic requests, and then allocates the service to each elevator in the group. The elevator car moves from the main terminal to the destination floor within its zone only. The Liu, Yaowu, et al. [12] focuses on the problem of more energy conservation. This problem solved by using the zoning technique.

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The study focuses on use heuristic algorithm to provide the best optimal solution using the genetic algorithm. Elevators consume energy in travel and a standby state. The elevators consume 70 percent energy while moving. This energy consumption may vary according to the traveling direction, traveling distance, and total traveling weight. The proposed system, use a fixed transit floor and initial floors. The study can extend for variable transit floors and by eliminating the limit of the zones. Rashid, M. M., et al. [13] use a fuzzy algorithm for car allocation. In a four-car elevator system, one used as a dummy elevator and controlled using a fuzzy logic controller. High-speed DSP board used instead of micro-controller. Zhang, Yine et al. [14] uses a fuzzy neural network to improve the service quality and performance of EGCS. The system needs human experience and knowledge. The study of Janne Sorsa et al. [15] focuses on future traffic prediction from historical information, taken from EGCS and accordingly dispatching of elevators. The research concentrates only on a single elevator to predict uncertainties in traffic. Generated Results do not anticipate the correct values as passenger scenarios change periodically.

The study of Albert So et al. [16] focuses on the hypothetical assumption of a three-dimensional elevator system, where an elevator can serve calls in three directions horizontal x, y, and vertical z. The system focused on the use of destination control algorithm where passengers provide destination information in advance, and by using this data, the system allocates elevators. Simulation presents results with operating elevators, which stops at only one single floor on each trip. Further work is going on using genetic algorithms. The study of You Zhou et al. [17] presents the algorithm for an elevator monitoring system, using the internet of things. The system does not focus on the scheduling of elevators instead; it focuses on the maintenance of elevators to avoid risks. Study of Shuo-Yan Chou et al. [18] focuses on the use of cameras in building lobbies to collect passenger information. Using this data system allocates multiple elevators to floors having more objects. Weiping, Henu, Xing, Yan and Chen [19] introduced an efficient dispatching algorithm with the help of Markov Decision process model along with recurrent neural network base reinforcement learning for achieving optimal dispatching policy. Zoning algorithms used in the study of Li, Zhonghua, et al. [20] creates problems when no. of floors and lifts increase, as it creates complexity in the zoning.

Many researchers focus on the use of Electronic Microchips with genetic algorithms and artificial intelligence algorithms. However, the processing capability of the microchips is not as effective as required. Neural network algorithms are difficult to understand and implement, as they require too much training. Not all these techniques show the desired results. Dynamic dispatching does not allow the use of fuzzy designs. In the static dispatching method, the system allocates every landing call to a particular elevator only once. Dynamic dispatching does a continuous assignment of elevators to a landing call. For every new landing call, the system re-allocates all landing calls. Fuzzy logic methods used in the studies cannot evaluate a global solution, as they are unable to operate information in parallel. They can process an up and down landing calls sequentially at a time without considering what happened next.

III. CATEGORIZATION AND COMPARISON OF ALGORITHMS

From the literature, different categories of algorithms are identified. These categories are fuzzy based algorithms, genetic algorithms, neural network algorithms, artificial intelligence algorithms, and zoning algorithms. Table I shows the different categories of algorithms used for scheduling of elevators in EGCS.

Different techniques used to schedule elevators in an EGCS compared and studied in this research study. The general categories are Fuzzy algorithms, Artificial intelligence, Neural Network, and Zoning algorithms. Table III shows the comparison of different methods surveyed from the literature review. Table II shows the merits and demerits of some methods found in this survey.

TABLE I Algorithm categories

Sr. No.	Domain Category	Reference paper nos
1	Artificial Intelligence	[6],[11],[20]
2	Fuzzy Algorithms	[1],[2],[3],[5],[9],[13]
3	Neural Network	[4],[14],[18],[19]
4	Zoning Algorithms	[8],[12]
5	Genetic algorithm	[7],[16][10]

TABLE II Comparison of Algorithm categories

Sr. No.	Method	Demerits	merits
1	Fuzzy Algorithm	Fuzzy Logic is a robust method. Fuzzy logic based controllers face a problem of memory faults, which affects the performance of fuzzy controllers. To avoid such type of the issues, the neural network techniques combined with fuzzy logic controllers. However, this combination increases the complexity of controller implementation. Unable to process the operations in parallel.	reduced waiting time improves the service quality and performance
2	Artificial intelligence, Neural Network	These technologies need expert experiences and training efforts to achieve good results. Neural network algorithms are difficult to understand and implement, as they require too much training.	optimal dispatching policy
3	Zoning	In heavy traffic, the zoning approaches become robust and less flexible. If the number of elevators and floors increase the zoning method becomes complex.	Energy consumption reduced, optimal dispatching policy

TABLE III Comparison from Literature Review

Sr. No.	Method Used	Merits	Demerits/limitations
1	Zoning- hybrid nested partitions and the genetic algorithm method (HNPGA)[7]	Solves the Scheduling Problem	Proposed system takes more CPU time. It is a challenging issue to develop such a system, which can effectively utilize advance information. Research need Further improvement to reduce CPU time.
2	Fuzzy Neural Network-Dynamic Programming Algorithm using DFG[4]	Solves the dynamic partitioning problem for up-peak traffic mode	No solution for down-peak traffic.
3	Used Monte-Carlo sampling to get Initial and destination floors of passengers [2]	Provides the foundation for further research in the field of elevator group control system	The study does not offer a solution to the scheduling algorithm.
4	Fuzzy Control algorithm[3][5]	The Comparison of the genetic algorithm and the neural network	The study provides a complex solution to the scheduling algorithm. Not proved where they meet customer requirements.
5	Elevator Dispatching Algorithm[15]	Prediction of traffic	considered single elevator
6	ANN, expert system and the fuzzy control theory[4][6][18]	Solves the Scheduling Problem	Limited knowledge & human experience
7	Zoning Algorithm[8]	optimal dispatching policy	Up peak traffic mode only
8	Fuzzy Algorithm- ETA Algorithm[9]	good performance for inter-floor and up peak conditions	Poor results in lunch peak or down peak conditions. Once the time interval is over the controller cannot detect changes.
9	ANN and the expert theory[11][19]	Dynamic dispatching system	Limited knowledge & human experience
10	Zoning- genetic algorithm[12]	Energy consumption reduced	Fixed transit and initial floors. The study can extend for variable transit floors and by eliminating the limit of the zones
11	Fuzzy Algorithm[13]	system performance is improved	DSP board has complex operations.
12	Fuzzy neural network [14]	improves the service quality moreover, performance	Human Experience and knowledge are required.
13	Zoning Algorithm[20]	optimal dispatching policy	As the no. of floors and lifts increase, the Complexity in the zoning will also increase.
14	Fuzzy Algorithm[3][1]	Reduced waiting time	Need a fuzzy controller and is not cost effective.

IV. EXPERIMENTAL RESULTS FROM LITERATURE

Following table shows the results generated for Average Waiting Time AWT of passenger and Average Journey Time AJT of a car for 12%, 15%, and 20% of the population in the down- peak Traffic. Similar results obtained for up-peak traffic mode. Near call is satisfied in many cases.

Table IV shows the average waiting time of passengers, average lift arrival time using a fuzzy algorithm, neural network algorithm and genetic algorithm for variable passenger arrivals in a specified time interval.

With the comparison of simulation results, it is observed that the fuzzy control algorithm gives the optimal solution than a genetic algorithm and Neural Network Algorithm. Waiting time for passengers is less in the simulation results using a fuzzy algorithm.

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Table IV Result generated by Simulation using fuzzy control, genetic, neural network Algorithm [3]

Passenger Arrival /5min	Fuzzy Control Algorithm		Genetic Algorithm		Neural Network Algo	
	Average Waiting Time (s)	Average Lift Time (s)	Average Waiting Time (s)	Average Lift Time (s)	Average Waiting Time (s)	Average Lift Time (s)
20	8.53	24.10	8.7	24.5	9.81	27.54
40	18.46	26.22	19.56	27.54	21.68	29.62
60	19.47	31.22	21.5	33.78	23.75	37.21
80	27.75	36.16	29.12	39.48	32.46	45.33
100	49.32	43.17	52.26	46.85	56.82	54.26

I. CONCLUSION

This paper studies computing techniques employed to optimize the efficiency of EGCS. Different algorithms used for scheduling of the EGCS are discussed and compared in this study. The fuzzy algorithm, zoning algorithm, and the artificial intelligence algorithm are the main categories of the scheduling algorithm. Zoning methods are too sophisticated to implement if the number of floors and elevators increases. The Fuzzy algorithms result in memory related problems. DSP boards used are complex and challenging to implement. Expert systems require human expert knowledge to provide a better result, which is not possible because human knowledge is limited. All the algorithms give better results at their level. To provide a better result in the dynamic scheduling and to overcome from the various demerits, need improvements in the algorithms.

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