Performance Optimisation of Knowledge-Based Elevator Group Supervisory Control System

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ABSTRACT

A new system for elevator group-supervisory control is presented in this paper. It addresses the problem of finding optimum routes for multi-lift system with the objective of reducing the overall trip time (waiting time + boarding time) for passengers. This has been made possible firstly by executing exhaustive search for all possible moves, and secondly by incorporating a computer vision system for counting people waiting at all landings.

Searching the whole space for best move is practically impossible in large buildings with four or more lifts, given the current computer technology. Therefore, pattern classification and clustering techniques, based on nearest neighbour or minimum distance, have been employed to minimise the decision-making or processing time significantly.

1.0 INTRODUCTION

Elevator group supervisory control systems can certainly outperform independently controlled lifts in all situations provided that a correctly designed control algorithm is used. These systems feature lift coordination and preventing unnecessary lift movements or stoppages, thus minimising wasted time [1].

Numerous algorithms have been proposed with the objective of reducing mainly the average waiting time, and sometimes the overall journey time. Traditional algorithms may share these objectives but they are different in the way the lift movements are optimised as well as their performance in different traffic flow situations (up-peak, down-peak, interfloor traffic, or a combination of these). Because of the insufficient data available to the group supervisory control, such as the number of passengers waiting at each floor and those inside the lifts, an optimum solution can not always be realised [2]. This becomes more evident when a mixture of traffic flow exists (e.g. up-peak and random interfloor traffic), or even in heavy interfloor traffic situations. The algorithm presented here has been especially designed to cope with these situations while keeping high performance during up-peak traffic.

2.0 RULE-BASED ALGORITHM

In the proposed approach, an exhaustive search is carried out to find the best move in a given traffic situation. But the definition of what that best move is may differ according to the specified targets or objectives. This may well be a waiting time, journey time, cost, power consumption or a combination of more than one. Therefore, the algorithm has to be designed to meet the required set of objectives. In some situations, there may even be a conflict between two objectives such as, for example, reducing waiting time and minimising power consumption. If the objective is to maximise the speed at which passengers reach their destination, then the algorithm should be designed to find a solution to reduce or minimise journey time (waiting + boarding) for all passengers. This would inevitably require some accurate data about waiting passengers as well as those on board.

The search for an optimum move is an exhaustive process in which all permutations are considered, and an index of merit Q is calculated for each move. The best move is the one which returns the highest Q. But how is this index of merit calculated? If we assume Q to be a function of the speed of transportation, then the following formula can be proposed. This is referred to as the PS/T algorithm.

$$Performance\ Index_{(Transportation\ Speed)} = \sum_{i=1}^{n} \frac{Pi.Si}{ti} \qquad \ldots\ldots \quad (1)$$

Where: n: total number of passengers
p: number of people transported
s: relative distance (journey's no. of floors)
t: total time (waiting + boarding)

The number of people waiting at each landing and in each lift, is known to the lift group supervisory controller since a people counting system has been realised [3]. This system requires installing cameras at all landings and in lifts to provide sufficiently accurate data about passengers, and would enable the PS/T algorithm to find the best move. In the following sections the architecture of the proposed system is described.

2.1 CONTROL RULES

The first part of the search process for an optimum move would ensure that the move under consideration is a valid one by complying with the following control rules:

- no 'up' move from top floor or 'down' move from bottom level.
- no reversal in direction if the lift is occupied.
- no 'stop' for passengers wishing to travel in opposite direction to that of the lift.
- no 'up' or 'down' move while gates are open.
- lift has to stop at all recorded destinations to drop its passengers.
- fully loaded lifts do not answer landing calls.

Those moves that meet all the above conditions are considered valid and are analysed during the optimisation phase. These rules also play a vital role in speeding up the search for the best move by dropping non valid moves. For example, lift carrying passengers up will not consider a 'stop' move to pick those passengers going down and vice versa.

2.2 OPTIMISATION RULES

In this phase of the analysis all valid moves are considered and each move returns an index of merit Q. These indices are compared and the move with the highest Q will be elected to be the "best move". For n lifts, each may move up, down, or stop, there will be a total of 3^n permutations for just one look ahead step. If more steps are to be considered the number of permutations will be increased exponentially. But, as was shown above, some of these moves may have already been identified as invalid moves hence reducing the search space.

The optimisation rules can be divided into two sets: those which consider people in lifts and those which consider people who are waiting. For each move, the benefits to both groups are added to find the total benefit from moving one lift in a certain direction. Repeating these calculations for other lifts would produce the overall Q for the specified set of lift directions.

For the purpose of structuring the system, passengers are considered as objects that belong to one of two classes: 'waiting' or 'in-lift' with the following properties:

start:	starting floor	stop:	estimated destination floor
dist:	|stop - start|	direction:	up or down
time:	waiting or journey time	q:	passengers' estimated merit

RULE-A (in-lift passengers):

For 'up' or 'down' lift movement, this rule estimates the merit factor, Q, for passengers in the lift provided they are travelling in the same direction.

$$Q_{est.(for\ n\ passengers)} = \sum_{i=1}^{n} \frac{L\_dist(i)}{|L\_stop(i) - new\_floor| + L\_t(i) + 1 + doors * (stops - 1)} \quad \ldots\ldots (2)$$

Where: prefix L-refers to in-lift passengers

L_dist:	estimated journey distance (no. of floors)
L_stop:	actual or estimated destination floor
new_floor:	next floor in the lift move
L_t:	passenger's time so far (waiting + boarding)
doors:	time to open and shut lift doors
stops:	number of stops in the present journey

All terms in the denominator are expressed in time steps, each represents the time taken by the lift to travel one floor. The returned value is proportional to the speed at which passengers are transported and also takes the waiting time of these passengers into consideration.

RULE-B (waiting people):

This rule affects the lift's next move by considering those people waiting at the landing. It determines the merit of moving the lift 'up' due to call registration at upper floor(s), or stopping the lift in order to pick passengers from current floor. In some cases the rule may cause some frustration by skipping waiting passengers in order to keep journey time for on-board passengers short. But this is not usually the case; for example, the rule sees a little benefit in stopping a lift, with so many passengers on board, to pick a passenger with little potential (i.e. short journey).

The rule is applied for an "up", "down", or "stop" move only when they are valid moves (i.e. the move has complied with all control rules as explained earlier).

$$Q = Q + \sum_{i=1}^{n} \frac{W\_dist(i)}{|W\_stop(i) - new\_floor| + W\_dist(i) + W\_t(i) + 1 + doors * stops} \quad \ldots\ldots \ (3)$$

For each of the possible moves, this calculation is repeated for all waiting passengers above or below the current lift position to: firstly determine the direction of the lift and secondly to assign the lift which is best for servicing a certain floor.

2.3 DETECTION OF PEAK CONDITION

Detection of up-peak and down-peak situation is an important aspect of all group supervisory systems. Different techniques or mechanisms are used to cope with peak condition. In most cases the up-peak traffic is assumed to take place at the main terminal for 10-20 minutes period, and therefore cars are automatically sent to the main terminal after they have served their last call. They are also allowed to park at that floor for a longer time or until a predefined level of load has been exceeded.

The main methods of detecting the up-peak situation are mainly based on weight measuring devices installed in the floor of the car or they may employ logic counters for up/down movements lifts carrying more than a specified load. These methods suffer from detection of false (short) peak traffic, and the slow response to sudden changes in the traffic pattern.

In the proposed approach which uses the people-counting system the detection of up/down peak situation is based on the rate of arrival of passengers at each floor. The system detects the peak situation if a certain floor has repeatedly shown highest number of people who are waiting over a predefined number of time intervals. The main advantages of this technique are summarised as follows:

i) It can detect the peak traffic at any floor including main terminal floor and responds accordingly.
ii) It responds to the sudden changes of the traffic pattern very quickly by monitoring number of people rather than waiting for the weight measurement. The same is applicable at the end of the peak condition.

3.0 SYSTEM IMPLEMENTATION

The rule-based lift group supervisory system has been implemented using a high level language in DOS environment, and the interface with the people-counting software has been established. The main modules that constitute the system (shown in figure-1) are:

i) Input module: which can be divided into three sub-modules:
- A user-defined data base containing parameters such as number of floors, lift capacity, opening and closing time of doors, etc.
- Initial condition: setup for position of lifts and distribution of people.
- Traffic pattern module: This module has been designed to allow the user to define the traffic pattern (up-peak, random interfloor traffic, definite trend, etc.) and the arrival

profile (persons/minute). A combination of more than one traffic pattern is also possible. This part can activate an internal passenger generator used only for performance measurement and analysis. Alternatively passengers data can be acquired from the people counting system.

ii) Control module: here the traffic situation is analysed and all valid moves are assessed in an exhaustive search for a move with the highest Q factor and whose output will determine the directions of travel of the lifts.

iii) Output module: this module has been designed to show users the entire situation and all necessary parameters for performance monitoring. It consists of two sub-modules:

- Graphics simulation of the building floors, waiting and in-lift passengers, lifts' positions, occupancy, movements, and doors status.
- Statistical data shown on display and also stored in a separate file for later analysis. These include for each floor: the number of arrivals, average waiting time, average journey time, and ps/t (speed). In addition there are ten user-defined thresholds that can be used to monitor actual waiting time and other indicators such as the 90 percentile.

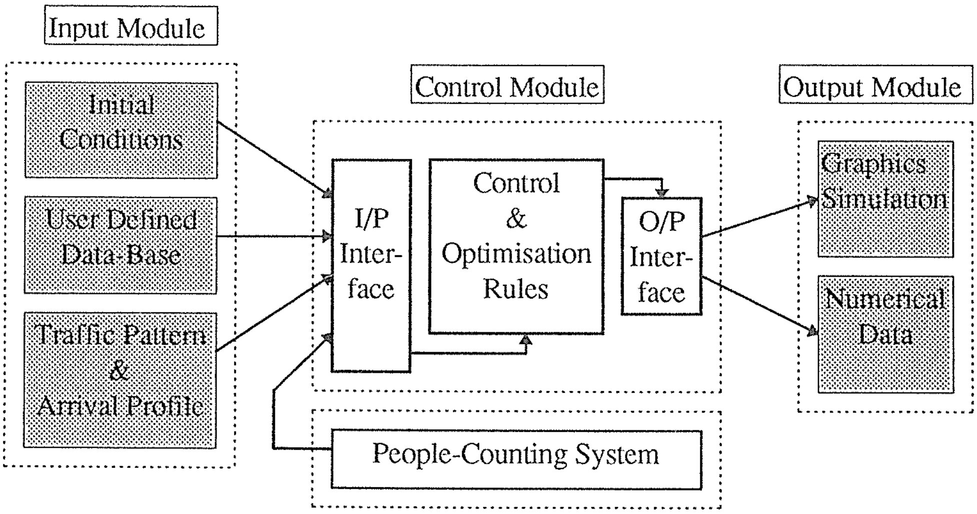


Figure-1: Structure of Lift Control and Simulation Software

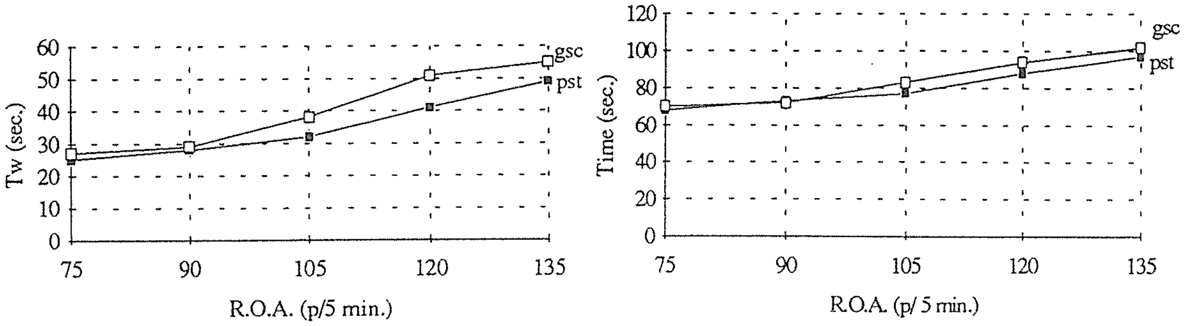
4.0 SIMULATION AND RESULTS

The software suite discussed above has been used to simulate the lift group supervisory control specifically the performance of the PS/T algorithm with different traffic patterns (up-peak, random interfloor, and definite trend) and a range of arrival profiles (75-135 persons/ 5 minutes). The tests have been performed on a ten-floor building model with a lift system of the following specifications: Number of cars: 4; Lift capacity: 15 persons; Stoppage time: 8 sec. (including time to open and shut doors); Speed: 0.75 m/s.

Two versions of the lift system have been implemented in order to allow the comparison in performance. The first one is based on the PS/T algorithm that uses data from the people counting system for optimisation, while the second is a conventional Group Supervisory

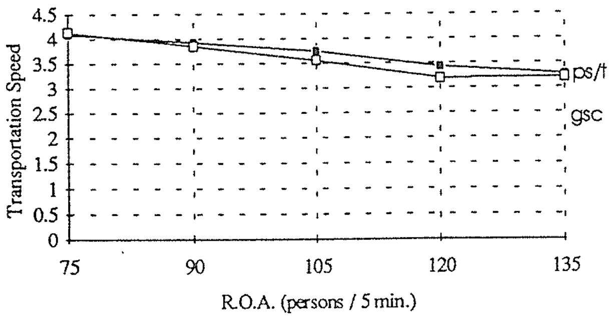
Control (GSC) governed by the control rules, explained earlier, and hence can only be activated by landing and car calls.

In the up-peak traffic pattern, results have shown a little difference in the average time, total journey time and transportation speed for all arrival profiles. This is mainly because the number of waiting passengers would have a little impact on the lift movements (in both cases, lifts stop at the main terminal to load passengers, usually up to a predefined load level, and distribute them at their destinations before descending back to the main terminal). However, the PS/T algorithm starts outperforming the GSC version when some random interfloor traffic exists, especially at higher rates of arrivals (ROA). Figure-2(a, b, and c) show respectively the average waiting time, average journey time, and the transportation speed for a traffic pattern with 50% random and 50% up-peak. It can be shown that a reduction in average waiting time can be up to 17% at high rates of arrivals, and around 12% in average journey time.



(a) Average Waiting Time

(b) Average Journey Time



(c) Passengers Transportation Speed

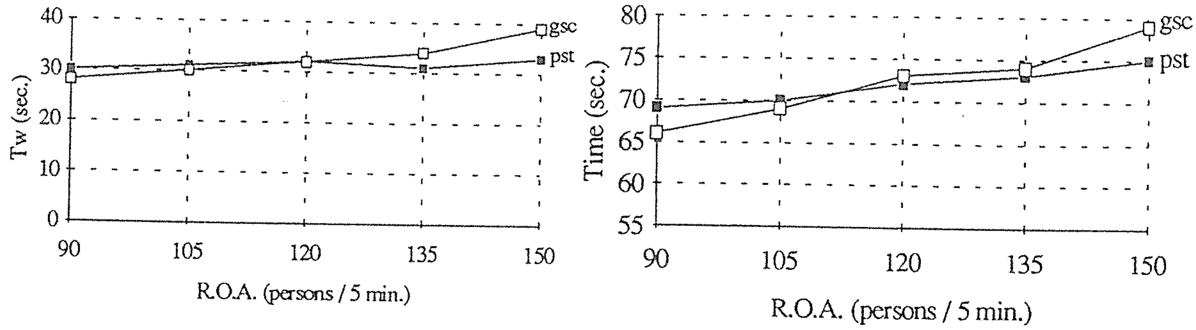
Figure-2: Comparison of Performance Measurements
(50% up-peak and 50% random traffic)

For a 100% random interfloor traffic, similar analyses have been carried out. Results show that as the rate of arrivals of passengers increases, both the average waiting time and the average journey time start to increase. However, the PS/T algorithm shows a better performance than the conventional GSC at higher rate of arrivals as shown in figure-3 (a, b). Similarly the decrease in transportation speed of passengers (figure-3 c) is less in the case of PS/T algorithm.

This performance would be significantly improved if the look-ahead search can be extended to two, three, or more steps. But the intensive computations required to perform the search for the best move would hinder such extension especially in large buildings with four or more lifts, given the current computing technology. For this reason data classification and clustering techniques[4,5], similar to those used in neural networks, have been investigated.

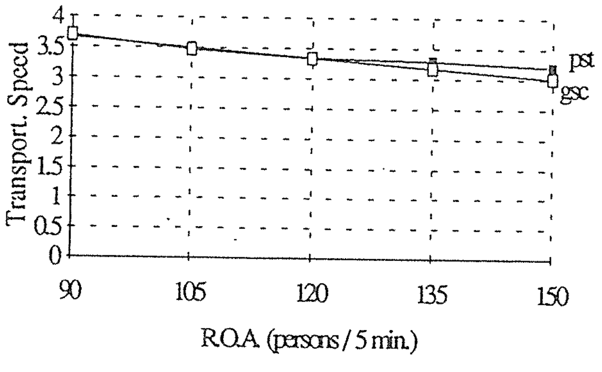
The entire search space can be divided into 3^n classes, each represents specific set of lift directions (e.g. four lifts would require 81 classes). The lift control system is run for a long time in order to produce sufficient learning set and the necessary information from each time step (vector) is stored in a data base for later classification. These vectors should contain all necessary information such as: landing calls, car calls, lift positions, lift directions, etc. which represent the input set and also the directions of the lifts as corresponding output set.

During the classification process the data base is searched and all parts of the learning set that have the same output are grouped in a unique class. Then, the centre point of each class is calculated and is used as a representative of that class leading to a massive reduction in the search space, and therefore makes the extension of the look ahead practical. This clustering technique has been developed and its application to the proposed lift control system has produced 84-90% accuracy. Further improvements, such as the elimination of overlapped (fuzzy) areas, to the system would significantly increase its accuracy.



(a) Average Waiting Time

(b) Average Journey Time



(c) Passengers Transportation Speed

Figure-3: Performance Measurement for Random Traffic

CONCLUSION

A rule-based lift supervisory system incorporating an automated people counting facility is presented. It comprises two sets of rules and performs an exhaustive search for optimum lift movements that can achieve highest transportation speed for passengers. With only one step look-ahead search it has shown a significant improvement in performance over conventional systems particularly at high rates of arrival. The intensive computations and the time taken to search all possible moves can be overcome by running the system once and using its data to learn a pattern classifier so that a future decision can be made very fast. The accuracy of this decision is currently around 87% and this can still be improved by further manipulation of the clusters.

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