Visual Interactive Lift Simulator

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Abstract

In modern high-rise buildings, a suitable control algorithm has to be chosen so that lifts can respond to passenger requests in such a way as to transport them quickly and efficiently to their destinations. The aim of the current work is to assess new scheduling policies and intelligent monitoring techniques, to aid the design of new lift systems and to improve the performance of existing installations. To achieve this, a lift simulator has been implemented to allow the modular comparison of alternative scheduling and monitoring approaches and to provide an accurate model of lift dynamics, landing calls and car calls, door opening times and passenger movements.

1 Introduction

Lifts simulators have been developed for two principal purposes, namely to aid the design of new lift installations and to assess the relative performances of alternative scheduling strategies. The current work falls into the second category [1]. The first lift simulators were built in hardware; modern software systems bring flexibility to the lift simulation, in terms of assessing performance using alternative solutions. As well as aiding the understanding of different traffic patterns, a visual lift simulator allows potential customers to view the performance of proposed lift installations. At the design stage, it is necessary to decide the number of lift cars which will provide sufficient handling capacity under the control of a suitable scheduling system, while maintaining efficient building space utilisation. As buildings and their function may alter, an adaptable control algorithm has to be chosen to provide flexible efficient transportation.

The conventional way of calculating the performance of lift systems is based on probability theory in conjunction with simplifying assumptions. For example at up peak, most calculations assume evenly populated floors, transportation of the same average load in each car from the ground floor and equal interfloor heights. However, the calculated interval (the average time between successive lift car arrivals at the main floor with cars loaded to any level [2]) and handling capacity do not give adequate information for all traffic patterns and a lift simulator is required to produce a more accurate description of systems performance under different scheduling algorithms, traffic patterns and building specifications. Using a lift simulator, different patterns of traffic can be tested and goals such as minimising waiting or journey time can be monitored to optimise scheduler performance and to produce an efficient building design in terms of serving of shops, restaurants, or entrances [2, 3, 4, 5, 6, 7, 8]. For example, simulation results have indicated that there is no direct connection between interval and waiting time. The interval depends on the number of lift cars and lift capabilities, while in addition to the lift performance, waiting times depend on passenger arrival patterns and, particularly at peak times, the performance of the scheduler [4, 5].

One of the most difficult problems in lift system design is the unpredictability of the traffic patterns, such as when the next landing calls is going to occur, how many passengers are behind a call, how long it will take them to get into a lift and which destination each is going to choose. The missing knowledge makes the task of providing optimum real time decisions by the scheduler impossible in practice. In general, the more we know about the building and lift environment and the more accurate the data supplied to the scheduler, the better will be its performance. An intelligent lift scheduler uses the assistance of a prediction system which analyses the daily traffic data of the lift system and compares it with previous analysed data in

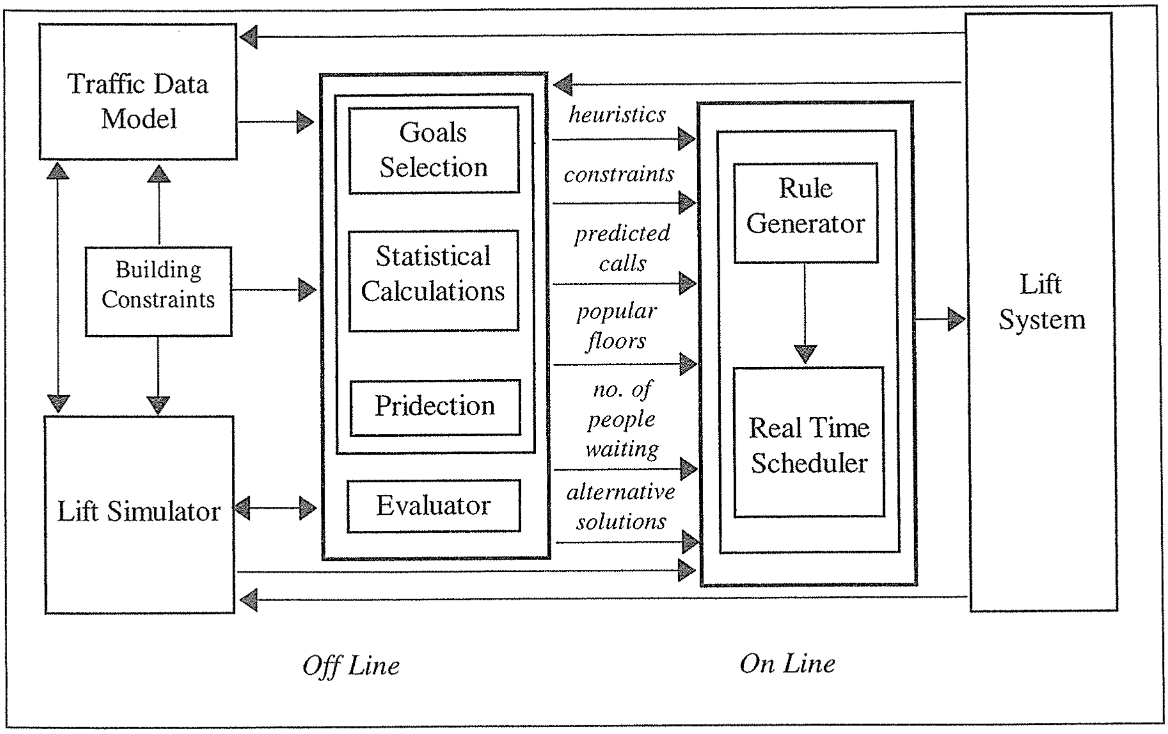

Figure 1 Intelligent lift scheduling system

order to identify general trends in the traffic density and distribution which helps in making decisions based on future expectations. At times of peak demands on a group of lifts, the need for an intelligent co-ordinated scheduling lift system is necessary to minimise the passenger waiting time and to prevent long queues developing. Rapid data processing by a simulator will allow its use as a part of a traffic monitoring system which observes traffic fluctuations and feeds back useful information to the scheduler. This paper describes the implementation of a lift simulator as a part of an intelligent real-time scheduling system, figure 1. In the following section a definition of the intelligent lift system is given and the significance of the use of a lift simulator as an essential part of its development. The remaining sections discuss the lift simulator itself and its future enhancements.

2 Intelligent real time lift scheduling system

A lift scheduler operates in continuous state space and in continuous time as a discrete event dynamic system; its state is not fully observable and the problem is non-stationary due to changing passenger arrival rates [9]. In modern lift scheduling systems, there may be a number of objectives or goals, such as minimising one or some combination of the following: waiting time, average waiting time, transfer time, crowding inside the car and energy consumption. In addition, it may be possible to simplify the complexity of determining the optimum route to the goal state by automatically identifying sub-goals, examples of which are landing priorities and parking policies.

In order to satisfy such of goals, an intelligent monitoring system is required to assist the real time scheduler. The monitoring system is responsible for analysing the domain knowledge available about the building and the traffic, and for providing the scheduler with the following.

- The strategy or the objectives that the scheduler must follow.
- A prediction of the traffic type, for example up-peak traffic early detection, the most probable landing call or car call for the next state, the number of passengers waiting, popular floors and priority floors.
- An evaluation of the current state which helps the scheduler correct its action and suggest alternative solutions.

Most of this information can be communicated off-line, that is, it need not be synchronised with the immediate real-time scheduling solution.

In general, the greater the quantity of knowledge that is maintained regarding the state environment, the better will be the performance of the scheduler. It is apparent that to achieve an optimum call allocation strategy, it is essential to know the current and future passenger traffic flows. The research work into the off-line systems will need to follow the stages outlined below.

- Make the most of the available traffic data with the maximum possible accuracy, for example car loads and photocells. Perform statistical analysis on traffic data rate calculations, identify and learn traffic patterns.
- Extract rules for strategy selection, prediction, evaluation and generating alternative solutions.
- Use a simulator as part of the off-line system to assist in data analysis and decision making.

To achieve the above, an accurate simulation of the lift system is required, which has the ability to generate information such as door, load, and position status of each lift car to provide different examples of performance in response to varying traffic levels. The literature includes examples of the use of intelligent systems, such as fuzzy logic and neural networks, which use lift simulation for testing, evaluating and assisting in the task of providing the best scheduling algorithm [9, 10, 11, 12, 13, 14].

3 Lift simulator

A lift simulator is a discrete event, fixed-time increment, dynamic, stochastic simulation of a group of lifts [7]. The simulation should give as close a resemblance to the real world as possible. Figure 2 shows the main modules of a lift simulator. The C programming language is used for both the simulator and intelligent scheduling system, using an IBM compatible PC. The initialisation stage defines information about the building such as number of floors, floor heights, lift speed, acceleration and door timing. We have used in our simulation examples of existing buildings with traffic models extracted from real traffic data. The simulator initialises the lift system at the beginning of the day when there is no activity in the building to a predefined parking floor for each lift ready to receive the early morning traffic. In the simulator the following actions are modelled: following a persons arrival, a landing call is generated, the scheduler assigns a lift to answer the call, car doors open, as passengers go in they press their

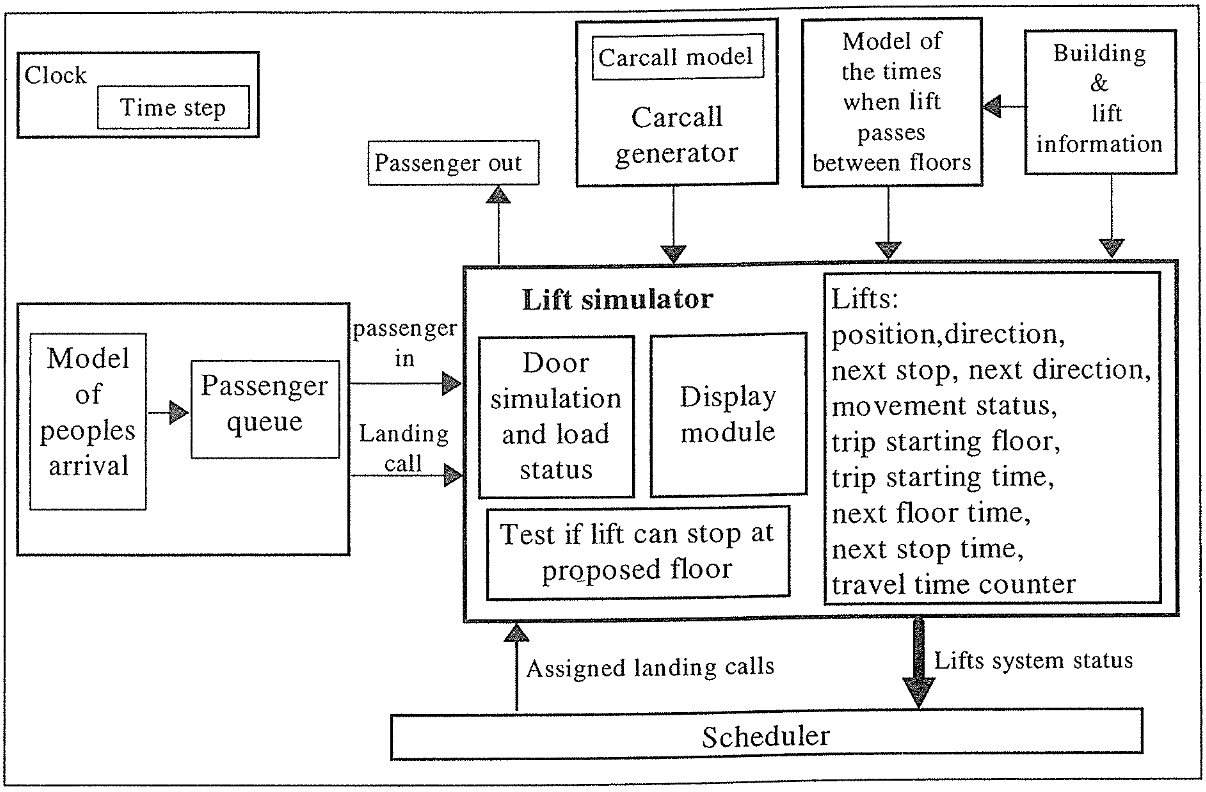

Figure 2 Lift Simulator

destination buttons thereby generating car calls, after the last passenger has entered the doors are closed and the lift moves to answer the car calls. At each time step the system state updates and the scheduler receives information of landing calls, lift car calls, position and status. The time step can be varied to meet any given accuracy requirement. As the day goes by, the traffic intensity varies from up peak time periods through normal activity, lunch peak period, normal activity again and finally down peak period. Under light traffic conditions, when there is no activity in the lift system, the time step can be modified so that the simulation jumps in time to the next person's arrival.

3.1 Simulator display

Figure 3 shows an example of the visual part of the simulator displaying the lift group activity The example shows an 18 floor building; the columns represent the individual lift shafts and the rows represent the floors (the floor rows have a colour different from those which represent distance between floors). The first row below the lift shafts labels the shaft indicating landing call directions (↓↑) and car calls (*). The remaining rows include status information regarding the lifts. The first two columns show the number of people behind up and down landing calls at each floor. For each lift shaft, four columns are displayed which are: car calls, lift car, assigned landing call down, and assigned landing call up.

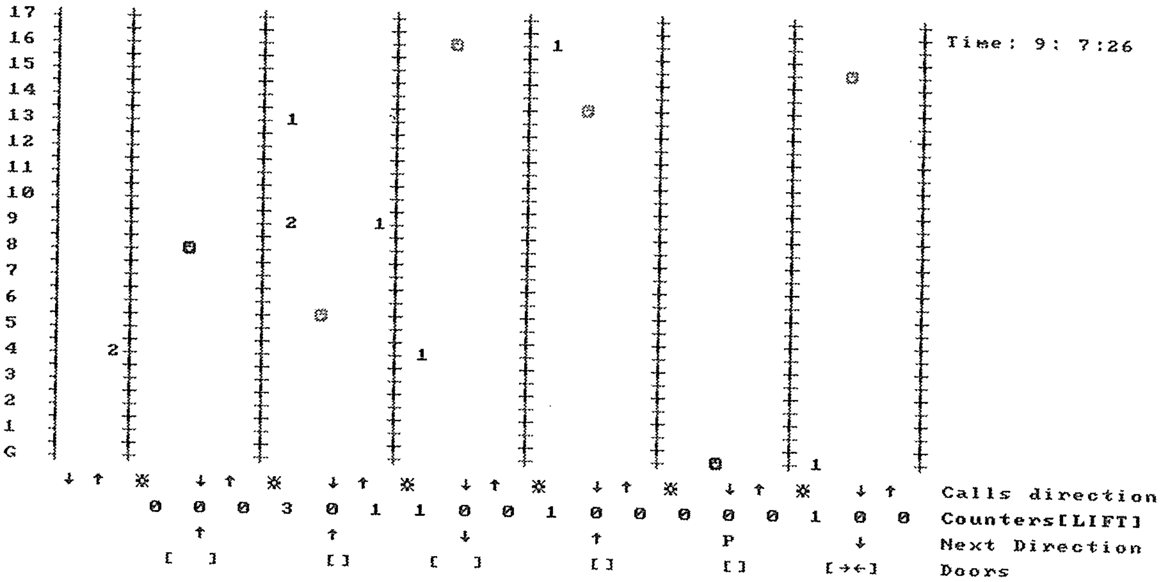

Figure 3 Screen capture of the Visual Lift Simulator

The numbers shown in these columns represent the number of people behind a call at each floor. The total number of car and assigned calls per lift are also displayed, in the same sequence, in the second row below the lift shafts. The remaining two rows show the lift's next direction and the door status. Lift movement between floors is indicated by scrolling the lift symbol which also flashes to show when it is moving, and the lift load status is indicated by changing the colour of the lift symbol. The clock is displayed on the top of the screen, and the display is updated every time step of the simulation. The user can freeze the screen at any time step to inspect closely the lift system status.

The simulator display can show a maximum of 18 floors and 6 lift cars; unserved floor numbers are not shown. For a building which has more than one group of lifts, each can be displayed separately, since each has a separate scheduler.

3.2 People and car call models

The people and car call models are extracted from real lift systems, overcoming the need to identify theoretically the traffic patterns. Although theoretical traffic calculations would still be needed in the planning stage, in an installation the initial traffic assumptions would be gradually replaced by real traffic examples when the intelligent lift system starts working in the building. Average arrival rates and passenger destination frequencies from each floor can be calculated from information such as car calls, landing calls, photocells, door status and lift moving status. Examples of full working hour days for varieties of traffic patterns, have been prepared to test the performance of the scheduler. The data patterns vary depending on the number of people in the building, the number of people using the lifts, popular floors such as those having a restaurant or smoking room, and time of the day, such as up peak and lunch time. The monitoring system has the responsibility of monitoring these patterns and identifying popular floors and expected peak times. For example, morning arrival in a building can start at 7 am, reaching its peak at 8 am and then begins to slow down again at 9 am. *The* same traffic pattern can repeat the next day or another pattern may emerge with arrival starting at 8 am reaching its peak at 8:30 am and slow again at 9:30 am. From these examples it would appear that for the same number of passengers entering the building, the intensity of traffic at 8 am and 9 am depends on when arrival begins and with what initial intensity. A random number generator with a Poisson distribution is used to determine the time of the next passenger arrival and the distribution of car calls which result from landing calls at each floor is used for generating car calls.

3.3 Lift car simulation

When the lift is assigned a landing call as its next destination it starts moving towards that floor. Jerk, acceleration, full speed and floors heights are used to determine the time a lift takes to make all interfloor journeys and these are saved in a lookup table. While a lift is moving the scheduler might assign other landing calls to the lift provided that the lift has enough time to decelerate and stop. As the lift stops at a floor, its doors start opening: figure 4 shows an example of door states and timings. Each time a passenger gets into the lift, the counter on the display is updated and a car call is generated in the direction of the landing call. As passengers leave the lift, the doors remain open in dwell state until a passenger arrives and a car call is issued (or until the lift is reassigned by the scheduler). Otherwise, at the end of the dwell

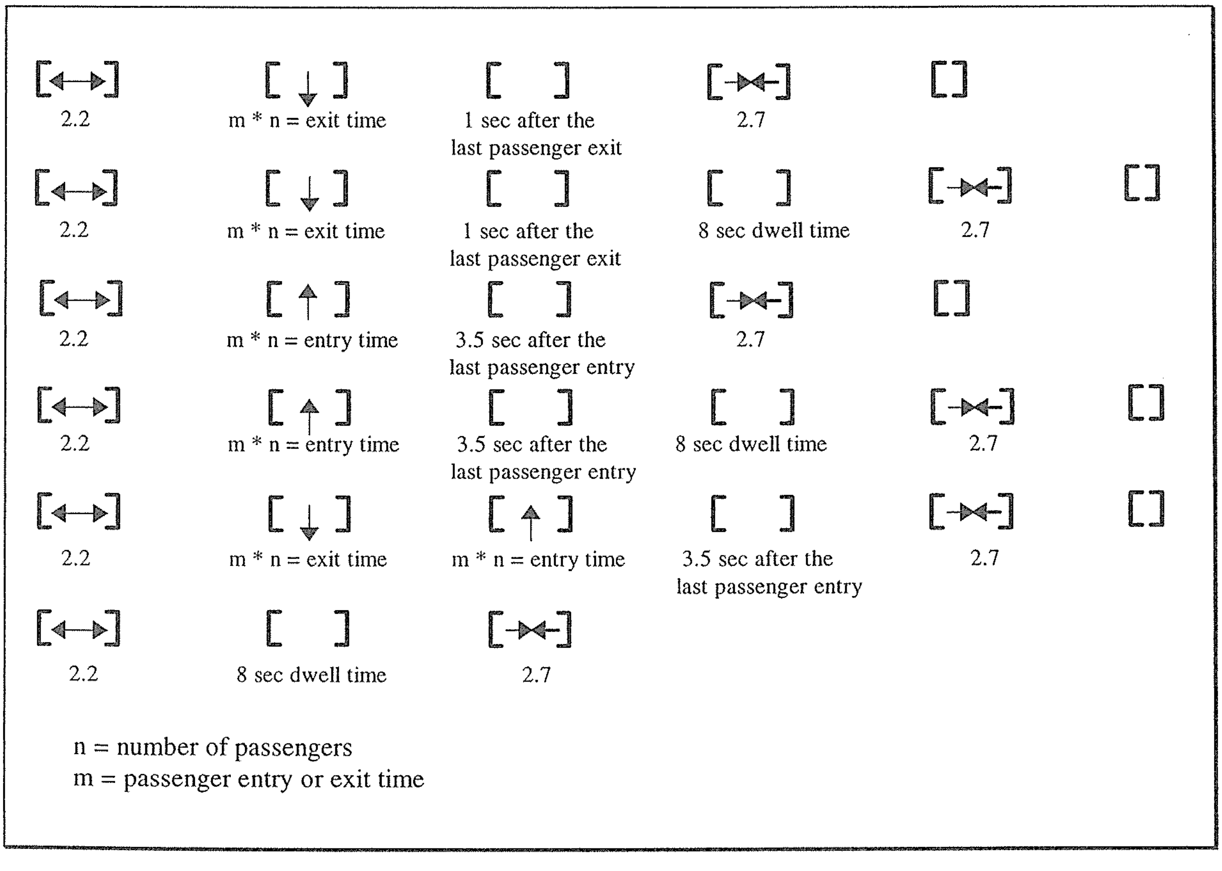

Figure 4 Doors states and time intervals (all times in seconds)

period, the lift doors start closing. While closing, if further passengers arrive, then it is assumed that they press the landing call button and the doors reopen as long as the number of passengers in the lift car is less than the maximum allowed number of passenger. The dwell period and the passenger's entrance and exit times are usually set at the beginning of the simulation, but, if required, these can be varied by the scheduler to suit the traffic intensity requirement.

The following can all be monitored for performance assessment purposes: passenger arrival time, landing call time, landing call cancellation time, door opening time, passenger entrance time, passengers car call, door closing time, car departure time and transfer time. For example, to check the validity of the traffic pattern used, the output of the simulator would be expected to be similar to that of the real system, using the same scheduler.

4 Conclusion and future work

Lift simulation is an essential part of lift system design and testing. In our simulation, we make use of the real system data available in order to maintain a close imitation of actual lift motion and time delays. The availability of the traffic model can replace the need to identify separately specific traffic patterns such as up peak and down peak with the monitoring system being given the responsibility of generating relations between floors and their traffic density.

Lift simulators can also be used as a part of a real time system to assist the scheduler in searching for the best assignment solution, for example by supplying the expected next lift state configuration which the scheduler can base its present decision. Also the performance of the scheduler can be tested in special cases, such as when one of the lift cars is out of order. The condition can either be induced directly from the keyboard at any time or by registering the time of occurrence before the start of the simulation run. The performance of any scheduler is greatly dependent on the quality of data it receives. The quality of data provided by the lift system can be improved by using simulation results. For example, during simulation, the lift simulator is able to supply the scheduler with better load status information than the data usually available for us from the real system. This can be used to assess the importance of attaching more accurate load sensors to a real lift.

A number of extensions to the current lift simulator system could be made to model passenger's behaviour. Under certain traffic conditions a passenger may choose to board a lift moving in the direction opposite to that of intended travel. Also under light traffic conditions, a passenger might press a button to close the lift car doors after getting into the lift.

Acknowledgement

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Biographical notes

Muna Hamdi received a BSc in control and system engineering in 1984 and an MSc in computer engineering in 1989. She has working experience of designing real time automatic control systems. Currently she is studying for a PhD in intelligent lift scheduling systems.

Dr D. J.Mulvaney has over ten years' experience of designing and implementing knowledge-based systems. These include an expert system for scheduling military aircraft training flights, a knowledge-based system to aid the assembly of surface mount components and a real-time artificial intelligence system for radar data fusion. Current work includes the investigation of artificial intelligence techniques for lift scheduling and the classification of surface texture data. He is a co-holder of an EPSRC award for the intelligent assessment of water quality using an on-line imaging nephelometer.