Recent Trends in Elevator Group Control Systems

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Abstract: The latest elevator systems have structural differences from traditional systems, such as the use of destination calls, or multiple cars in the same hoistway. This requires the development of new elevator group control systems, which is best done by adopting modern soft-computing methods. We review some of these systems and the results of research so far, and suggest further directions of research.

1. Introduction

Elevator group control systems have a large effect on the feasibility and usefulness of buildings, especially modern high-rise buildings, so their continuing development is an important area of research. At present in many cases the main target of development is to improve the traffic handling capacity. In addition to existing solutions, like double-deck elevators and destination hall call systems, multi-car elevator systems are receiving attention these days. These systems require the development of new control algorithms, and this usually involves the introduction of various intelligent control methods. In this paper we review these developments, as well as some analytic approaches to the study of elevator group control systems.

2. Structure and Operation of Elevator Systems

The purpose of new developments is to improve the handling capacity of elevator systems without increasing the required space in the building. We review the most important systems already used in practice, or proposed as future generations.

2.1 Destination Control Systems

An elevator group can carry more traffic if the elevators execute more trips in a given time. This can be achieved by reducing the number of stops during a trip, if passengers are directed to cars according to their destinations. This principle is shown schematically in Fig. 1.

The destination control system is most effective in up-peak traffic. A current research topic is how to improve its operation during other traffic conditions.

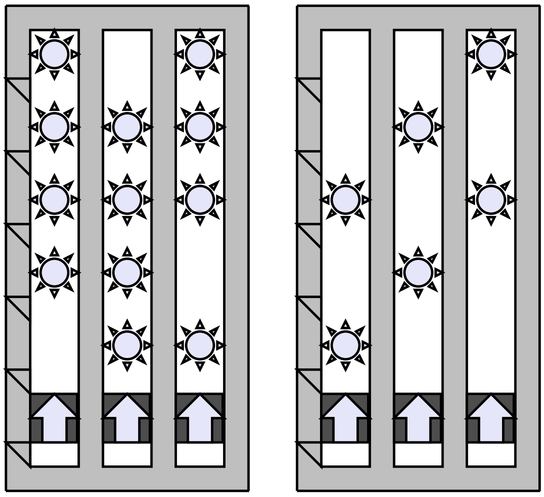

Figure 1. Principle of Destination Grouping

2.2 Double-Deck Elevator Systems

As a relatively straightforward way of operating two elevator cars in the same hoistway, we can stack them on each other and drive them by a common traction drive. This double-deck elevator poses many new challenges to control system designers, by the various constraints and control objectives specific to this system.

The most effective way of operating double-deck elevators is by serving odd and even floors exclusively by the lower and upper elevator decks. This operation allows simultaneous service to two floors, and reduces drastically the number of stops. However, passengers cannot travel between even and odd floors, so the use of this operational mode is limited.

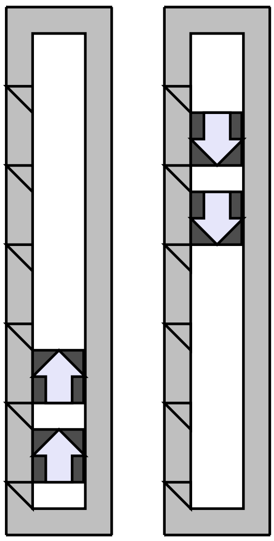

Figure 2. The Double-Deck Elevator

A relaxed, less restrictive operation is called the 'semi-double operation', where passengers from the odd and even terminal floors still ride only the corresponding lower or upper deck, but other floors are served freely. Efficient control of the semi-double operation is a major and not completely solved problem of elevator group control.

2.3 Multi-Car Elevator Systems

The multi-car elevator system is a revolutionary development, with the first actual systems already in operation, and further developments expected in the near future. It promises a dramatic improvement in handling capacity, while allowing the reduction of the space occupied by elevators in the building.

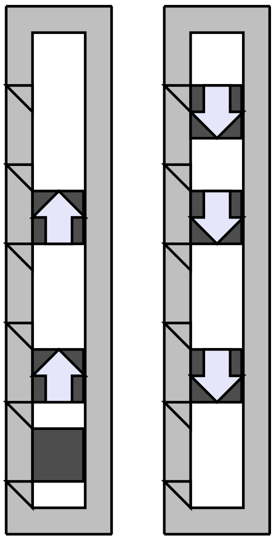

Figure 3. The Single-Shaft Multi-Car Elevator

Historically there had been many proposals for operating multiple elevators independently in the same hoistway, including circulating systems, or network-like systems with the ability of elevators to overtake each other. However, at present the only viable version seems to be the 'single-shaft multi-car' system, shown in Fig. 3. Mechanically, this system is almost identical to traditional elevators, as the elevator cages move only vertically, at all times staying connected to fixed rails and always ready to stop safely. However, this mechanical simplicity comes at the price of complexity in control.

The multi-car system requires a completely new control methodology. Because of the large potential number of elevator cars, the scheduling of service becomes difficult. On the other hand, since in contrast with other elevator systems, the individual elevators can no longer operate independently, there are severe restrictions on the available routes that the cars can take. Efficient operation is relatively easy in case of some very simple traffic conditions, but in general it is a major and mostly open research problem.

3. Control of New Elevator Systems

Elevator systems are designed to handle all traffic conditions that are expected to occur in a given building. New control algorithms will be effective if they can deal with not only just some representative conditions, but with any complex situation. In the examples below, we have used common, state-of-art control methods, which are best suited to certain simple traffic situations, but we shall see that their performance is limited, indicating the need for more advanced control methods.

The most basic passenger traffic condition in office buildings is the so-called 'Morning Up-Peak' traffic, when there is a large influx of people coming to work. In the most simple case, we can assume that other traffic components are negligible, and the elevators only need to pick up passengers in the lobby and deliver them to their offices.

We can compare the performance of the above elevator systems for the up-peak condition, by plotting the average waiting time against the traffic density, and observing the limit, i.e. the handling capacity. A typical result is shown in Fig. 4. Each of the new systems shows improvement on the traditional system, which is not surprising, since they were basically designed for such traffic.

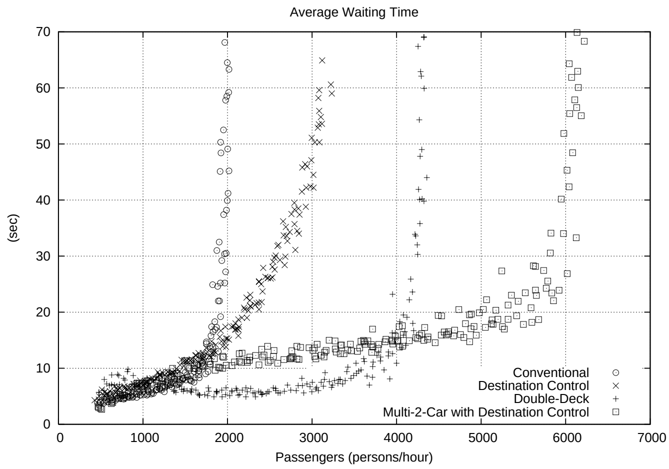

Figure 4. Comparison of the performance for up-peak traffic

However, the situation changes when we look at other performance measures. An example is shown in Fig. 5, showing the average waiting time behavior for a traffic that includes inter-floor movements. In this case, the performance improvement of the destination control system essentially disappears. This is just one example that illustrates the need for designing control methods for improved performance, in all buildings and for all traffic conditions.

Many new control methods are proposed for the new elevator systems, and we can review only a small selection here.

3.1 Group Control of Destination Control Systems

While the destination control system is effective in increasing the handling capacity and can also reduce the service completion time, it might cause longer waiting times, by not allowing all passengers to board the first departing car. Such effects can be reduced by careful control strategies, such as the dynamic optimization proposed in [1] and [2].

One powerful optimization method that has been successfully applied to the group control of destination control systems is the ES (Evolution Strategy) method.

The state of the elevator system is evaluated by a neural network, which outputs the control decision (hall call allocation) signal. The connection weights of the neural network are adjusted by ES so as to minimize one or more system per-

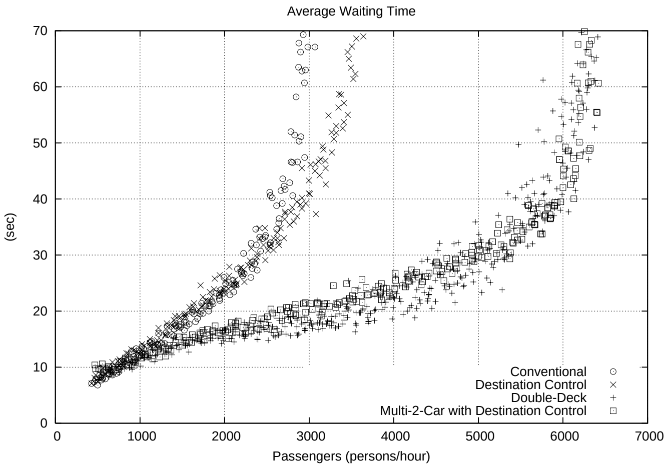

Figure 5. Comparison of the performance for general traffic

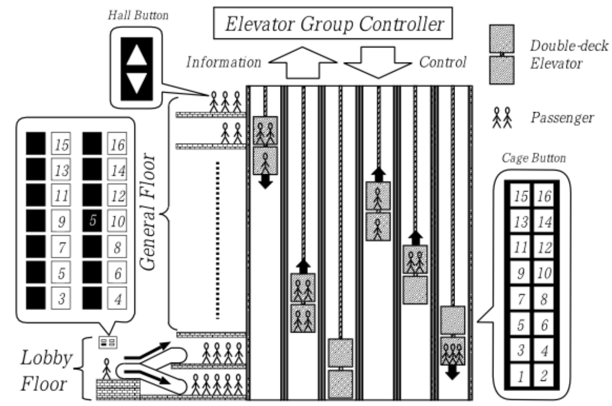

Figure 7. Control of Double-Deck Elevators

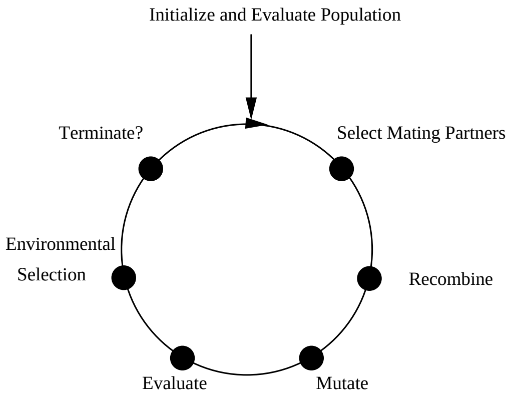

Figure 6. The Evolution Strategy Method

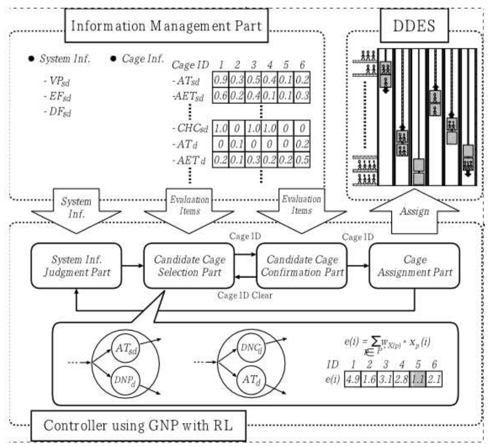

Figure 8. The GNP Controller for Double-Deck Elevators

formance measures. In the research of [6], the average service time has been minimized, obtaining better performance than with heuristic control rules.

3.2 Group Control of Double-Deck Systems

The control of double-deck elevators must take into account their special conditions and requirements. For instance, when there are people boarding or leaving only one of the two elevator decks, passengers riding the other deck are inconvenienced, so the occurence of such events should be reduced.

One promising approach is based on the automatic generation of suitable control rules by GNP (Genetic Network Programming) [4], which allows incorporating such special items in these rules.

The control system proposed in [4] is composed of network nodes, which propagate a decision event while evaluating the system state with respect to the required decision.

The nodes and connections in the GNP network can be adjusted by various optimization methods. Among the successful methods tested are genetic algorithms, reinforcement learning, and ant-colony optimization.

3.3 Control of Multi-Car Elevators

In contrast with the above systems, which can be considered extensions of traditional elevator systems, the MCE poses a completely new challenge. One approach involves the creation of a control system capable of expressing a wide range of policies, and tuning it by an optimization algorithm. An example is EBP-GA [8], which uses 'exemplar-based policy' for the control engine, and tunes its rules by real-valued GA.

Recently a highly successful competition has taken place under the supervision of the Japanese Institute of Electronics, Information and Communication Engineers (IEICE) [9], where many university teams have submitted their MCE control methods to compete for the best performance on a set of test problems. The ideas of these teams are giving a new impetus to elevator control research.

Finding effective and practical control methods for MCE systems is still an open problem, which is important not only for the elevator industry, but also seems to have implications

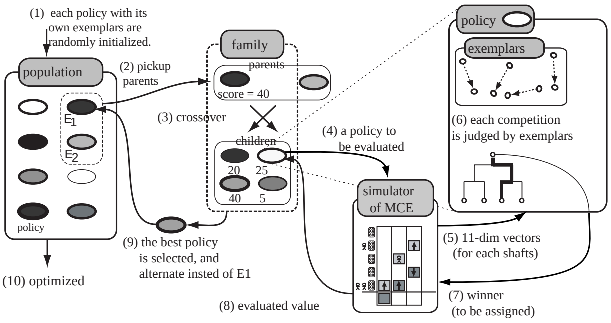

Figure 9. The EBP Method for Control of Multi-Car Elevators

in a wider area. There are many transportation systems, e.g. demand buses, stacker cranes, AGV systems etc., that have similarities with MCE systems. If a general methodology is found for these systems, we can expect it to result in efficient algorithms.

4. Conclusions and Further Research

The research of control methods for new elevator systems is an ongoing field, with some promising results but no definite solution yet. It is expected that with the participation of researchers from different fields, like optimization, scheduling, soft computing, and artificial intelligence, some generally useful algorithms will be found, that will have significant economical impact on building systems.

Elevator group control is one of those fields where most results are obtained by simulation experiments. Thus optimization methods must cope with the stochastic, noisy nature of simulation. Robust optimization in the presence of noise is an important ongoing research direction [10], [11], promising further improvements in elevator group control.

A very important but as yet undeveloped direction is the search for analytic, preferably closed-form solutions to elevator control problems. Some promising results have been already published [12], [13], and more can be expected from the field of “Competitive Analysis” [14].

New results in elevator group control can inspire advances in related fields, including the control of traffic and material handling systems.

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