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PASSENGER BEHAVIOUR IN ELEVATOR SIMULATION

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ABSTRACT

Elevators should be an integral part of a building transportation system. However, the integration of several transports and their ability to handle different kinds of passengers can usually be verified only in practice. Elevator planning typically assumes passengers with standard characteristics for one elevator group at a time. KONE Building Traffic Simulator (BTS) is able to simulate the traffic flow of a whole building with multiple transports. It also models the behaviour of various passenger types, such as adults, children and disabled people. In this article, the BTS passenger model is described and simulation cases are used to show the effect of passenger modelling.

Keywords: Passenger behaviour, elevators, simulation

1 INTRODUCTION

The transportation system consists of several types of transports in complex buildings. The overall capability of such transport systems cannot be analyzed by standard traffic-planning methods. A deeper understanding of the transportation capability during one day is obtained by simulating daily passenger traffic patterns (Siikonen 2000). For this purpose, elevator traffic simulators have been developed (Lustig 1986, Barney 1988, Siikonen 1993, Peters 1998). Passenger behaviour has not been previously included in elevator traffic simulators. In this paper, the model of human decision-making in transportation systems is described.

When planning elevators in buildings, passenger traffic is estimated roughly. Usually, up-peak traffic is assumed. Passengers are assumed to move in or out of a car within about one second, and each passenger is assumed to weigh 68-80 kg depending on the applied standard. A passenger occupies 0.15-0.22 m2 of floor space inside a car depending on the size of the person.

In elevator traffic simulators, passenger arrival floors and destination floors are typically generated randomly following the population distribution in the building. Arrival times usually follow a Poisson process. Passenger transfer times and other parameters are the same as in elevator planning. Passengers move ideally. On arrival, passengers give landing calls and wait in the queue until a car arrives. After entering the car, passengers give car calls and travel to the destination floors where they exit the car. In elevator traffic simulators, passengers act as elevator designers expect, in order to produce optimistic simulation results.

In addition to elevator planning, simulation offers a unique environment to test group control features realistically. To achieve a realistic simulation environment, diverse traffic patterns and passenger attributes should be modelled. When simulating traffic in buildings with several transportation devices, modelling passenger behaviour also becomes an issue.

2 BUILDING TRAFFIC SIMULATOR

In a typical elevator traffic simulator only one elevator group is simulated at a time. Time delays, traffic patterns and behaviour are similar for all passengers. In real buildings, there can be several tenants in the floor area served by one elevator group. In addition, tenants can have different traffic patterns and passenger characteristics.

The Building Traffic Simulator (BTS) simulates the passenger traffic of the whole building. Several types of transportation devices can be defined, such as elevator groups, escalators and stairs. Passengers use the available transport devices on the route to reach their destination floor. In this way, the simulation results include the interaction between the transportation devices.

BTS provides three advanced passenger-related features: an advanced passenger generation algorithm, characteristics of different types of passengers, and passenger behaviour.

2.1 Advanced passenger generation

In BTS, passengers are generated according to their location in the building. One or more tenants occupy each floor of the building with their relative proportion defined. Furthermore, each tenant is divided into one or more passenger groups with their own characteristics. This enables the modelling of non-standard passengers.

Tenant-specific traffic patterns are defined by the relative traffic components: incoming, outgoing, intratenant and intertenant. Intratenant traffic means interfloor traffic inside one tenant, and intertenant is interfloor traffic between separate tenants, as shown in Figure 1. The components are analogous to the incoming-outgoing-interfloor components related to a single elevator group, but are relative to the tenant.

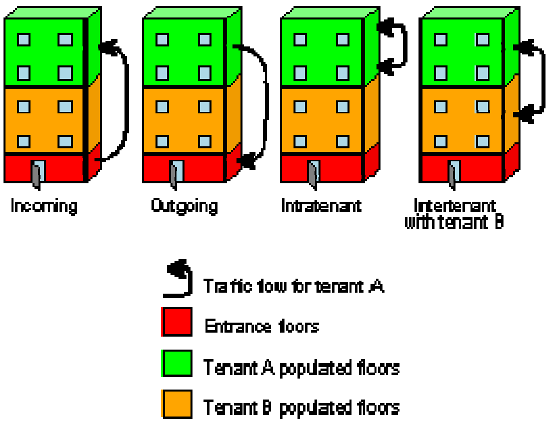


Figure 1. Components of tenant-based traffic definition

The simulation is divided into separate time slices of varying lengths. The traffic pattern is defined separately for each time slice and tenant. A realistic approximation of whole-day traffic is generated if the traffic patterns are specified in time slices of five minutes, as indicated in Figure 2 below.

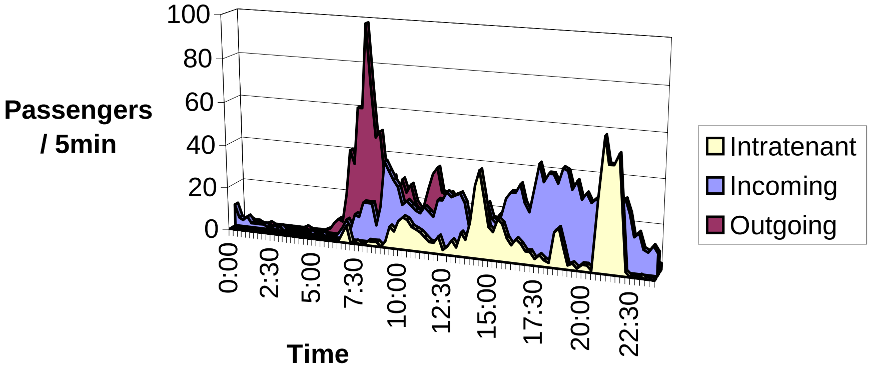


Figure 2. Time slices for passenger generation in a one-tenant residential building.

Time-dependent and tenant-based traffic definition is needed, because incoming, outgoing or interfloor traffic with no time dependence is not enough to properly describe the traffic in a large building. For example, the traffic flow to a restaurant floor of the same building during the lunch hour can be defined.

2.2 Passenger characteristics

Each generated passenger belongs to a passenger group. All passengers belonging to the same group share their characteristics. Passenger groups model common passenger categories, e.g. adults, children, disabled, shopping trolleys, building inhabitants and visitors. Because each tenant has its own distribution of passenger groups, the traffic flows have their own passenger composition.

There are two types of passenger characteristics: physical and behavioural. Examples of physical attributes are walking speed, transfer time, space demand, appearance and ability to use certain transportation devices. Passengers can be normal-sized adults who are familiar with the building, or slow, space-consuming and unable to use stairs such as people moving hospital beds, as shown in Figure 3.

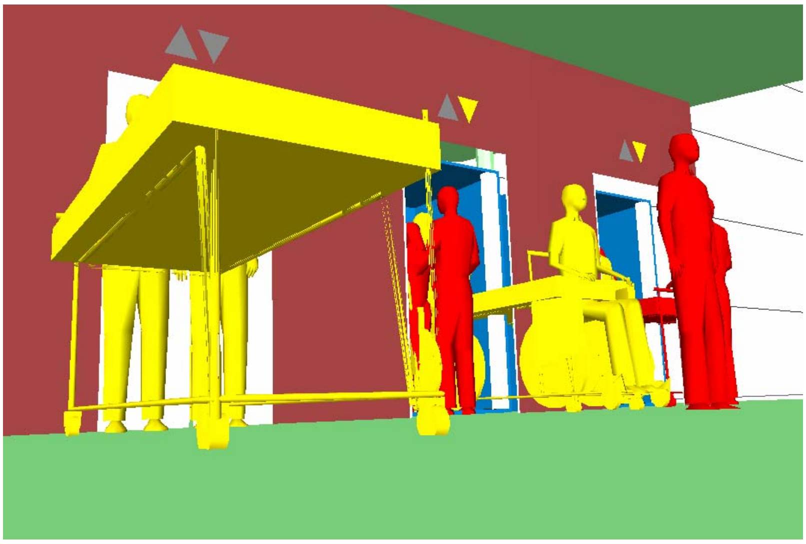


Figure 3. Some passenger types that can be defined in BTS

Behaviour characteristics, on the other hand, specify how the passengers behave in the simulation world. Simulated passengers exhibit certain behaviour, such as the tendency to favour escalators as transportation device, to avoid crowded areas, to avoid walking long distances, or to use staircases for very short distances between floors (Peters et al 1996). By changing the configuration of the behaviour characteristics, passenger groups can be made to behave in various ways.

Characteristics are needed to describe realistic passengers, e.g. people carrying heavy bags in shopping centres. In contrast to homogenous passenger composition typically assumed in simulators, they allow modelling the heterogeneity of real passengers.

3 PASSENGER BEHAVIOUR AND ROUTING

In large buildings, passengers may have to use several transportation devices on their route to the destination floor. There can be thousands of route combinations for passengers to move from one floor to another. In a building simulator, there must be an algorithm for routing the passengers. If the routes are chosen randomly, or with some simple rules such as “use minimal amount of transports”, the result is unrealistic; unnecessary congestion will form in one transport, whereas another will be completely free of passengers.

One solution is to maximize the traffic flow with some routing or maximum-flow graph algorithm. With multiple transports and complicated passenger generation, this would result in a very complex and slow router. Besides, it could result in too optimal a routing, e.g. a passenger could descend 30 floors in a staircase just to maximize the traffic flow. To achieve realistic decision-making of the passengers’ routes, the subject is viewed as behavioural rather than a routing model of passengers. Observing fundamental transportation-related behavioural patterns of real passengers and mimicking them in the passenger model, the important aspects of passenger behaviour are captured, which leads to realistic routing.

The behavioural model is implemented using ideas of behaviour-based artificial intelligence (AI) (Arkin 1998). In behaviour-based AI, intelligent behaviour is achieved by designing robots or software agents to show appropriate, often very simple but robust, behaviour patterns, rather than designing for the end goal itself. (Maes 1994) In BTS, passengers are designed to show typical human behaviour, such as avoiding already visited places. The routes will emerge rather than being explicitly produced. Each passenger is an autonomous agent who makes his own decisions. There are no pre-defined routes; whenever a passenger needs to make a decision about where he should go next, he takes the path that reflects his behaviour at that moment. There is very little planning beforehand.

As shown in Figure 4, the agent has two main components: router and reactor. The router models the passenger knowledge of the building layout and ensures that the passenger finally reaches his destination. The router is implemented by representing the building as a graph with a node for each transportation device entry. When a passenger has to choose his next destination, the shortest available route is searched from each neighbour node. A probability distribution is formed from estimated journey times using the available routes.

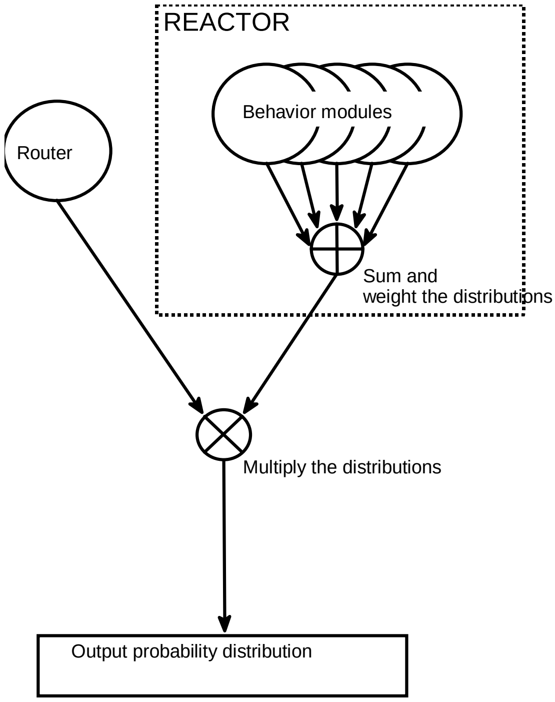


Figure 4. BTS passenger behaviour model architecture

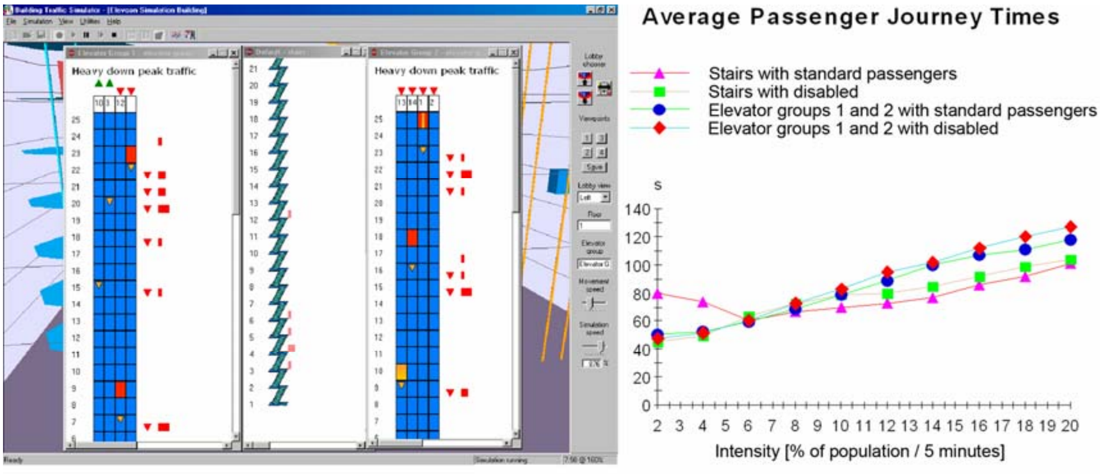
The reactor contains behavioural modules. Each of them represents a common behavioural pattern. Each module makes its own estimate of the quality of the available paths based on its own judgment. For example, the module representing reluctance to walk long distances favours paths that contain no walking. The probability distributions of all the modules are weighted using the tendencies in passenger group characteristics (Section 2.2) and summed. The outputs of router and reactor are combined by multiplication. The result is the probability distribution for possible routes; the preferred routes have higher probabilities. The final decision is drawn by random from this distribution.

As the weights of the behavioural modules are the tendencies configured by passenger group, passengers behave in a number of ways. The elderly are reluctant to use staircases, whereas the disabled may not want to move horizontally more than necessary. The behavioural passenger model offers a simple mathematical method to combine configurable behaviour and route selection in an effective way.

4 RESULTS

A test case was simulated using BTS where passenger routing in a building with 25 floors was tested. Two identical elevator groups with four elevators serve all floors and there is one 900 mm wide staircase in the building. Down-peak was simulated with different traffic intensities Two simulations were performed: one with a standard passenger group, and another with 90 per cent standard and ten per cent disabled passengers. The walking speed of normal passengers is 1.0 m/s, in stairs it is 0.6 m/s, and of disabled passengers it is 0.4 m/s. The disabled people always use elevators and occupy the space of four persons inside a car. The transfer times of disabled people in and out of the car is three seconds.

In Figure 5a and Figure 5b, the test arrangement and the simulation results as a function of traffic intensity are shown, respectively. Average passenger journey times include waiting time at the lobby and ride time inside the car, or walking time to the destination floor.



(a) (b)

Figure 5. BTS display of the test building (a) and simulated passenger journey times

In Figure 5b, four curves are shown. The average journey times for elevator groups 1 and 2 were about the same, as can be assumed, which was the result of the routing. This is a minimum requirement of sensible routing: if there is no reason to prefer one route to another, their usage should be approximately equal. In the figure, the average of the two groups is shown for standard passenger traffic, and for traffic including 10 per cent disabled people. In the second case, average journey times become longer since the cars are filled more easily and it takes more time for the disabled people to get in and out of the elevator cars.

Passengers also use the staircase. In light traffic, normally there are only a few random staircase users, because there is plenty of space in the elevators and it is more convenient to use them. As traffic intensity increases, queuing begins in the elevator lobbies and in the lower part of the building, passengers start to use the staircase. Journey times of staircase users for standard passenger simulation drop because the staircase traffic is concentrated in the lowest floors. When traffic intensity is 20 per cent of the population in five minutes, there is heavy queuing in elevator lobbies and passengers descend the stairs more often even if it takes a long time. Staircase journey times grow. In the case of disabled passengers, passenger routes become more asymmetric than in the standard case. Passengers start to use the staircase more, and journey times for staircase passengers become longer than when simulating one passenger group only.

5 CONCLUSION

In this paper, modelling of passenger traffic in an elevator traffic simulator more realistically than has been done earlier was described. In simulating building traffic, enhanced passenger models are required. In particular, a behaviour model is needed, when passengers have to make decisions to determine the best routes to the destination floors in environments with multiple transportation devices. Traffic generation, passenger characteristics and a behaviour-based AI model in BTS were introduced.

The effect of passenger routing was studied by a simulation case. Passenger journey times in symmetrical elevator groups were about the same. Times were longer both in elevator groups and in the staircase in the case of ten per cent of passengers being disabled. Journey times in staircases were shorter than with elevators since people from the lower part of the building used the staircases.

The characteristics and behaviour of passengers affect the simulation results. Simulation is the only way to determine the effect of diverse passenger types in their service times, and traffic handling capability of transportation devices. Modelling passenger characteristics serves various needs, such as simulating goods transportation, bed lifts and the effects of heterogeneous passenger characteristics. Even in simulating a single elevator group, passenger characteristics such as space demand or transfer times have an effect on the simulation results.

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BIOGRAPHICAL DETAILS

Tuomas Susi works as a Research Engineer in KONE Corporation Research Centre, Hyvinkää. He specializes in traffic simulation and is one of the key developers of BTS software. At present he is finishing his Master's thesis on human behaviour modelling in building transportation systems, at Helsinki University of Technology.

Janne Sorsa received his Master of Science degree in applied mathematics from Helsinki University of Technology in 2002. He is a Project Manager in the Major Projects Unit of the KONE Corporation and is specialized in elevator traffic and control systems. He is located in KONE Corporate Offices, Keilasatama, Espoo, Finland.