Applied Soft Computing 24 (2014) 31–39

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

An intelligence-based route choice model for pedestrian flow in a transportation station

J.K.K. Yuen [a,*], E.W.M. Lee [a], W.W.H. Lam [a,b]

[a] Department of Civil and Architectural Engineering, City University of Hong Kong, Tat Chee Avenue, Kowloon Tong, Hong Kong (SAR), PR China
[b] MTR Corporation Limited, MTR Headquarter Building, Telford Plaza, 33 Wai Yip Street, Kowloon Bay, Hong Kong (SAR), PR China

ARTICLE INFO

Article history:
Received 13 December 2012
Received in revised form 10 June 2013
Accepted 29 May 2014
Available online 15 July 2014

Keywords:
Artificial neural networks
Intelligent system
Crowd movement
Evacuation
Human behaviour
Transportation

ABSTRACT

This study proposes a method that uses an artificial neural network (ANN) to mimic human decision-making about route choice in a crowded transportation station. Although ANN models have been developed rapidly and widely adopted in various fields in the last three decades, their application to predict human decision-making in pedestrian flows is limited, because the video clip technology used to collect pedestrian movement data in crowded conditions is still primitive. Data collection must be carried out manually or semi-manually, which requires extensive resources and is time consuming. This study adopts a semi-manual approach to extract data from video clips to capture the route choice behaviour of travellers, and then applies an ANN to mimic such decision-making. A prediction accuracy of 86% (ANN model with ensemble approach) is achieved, which demonstrates the feasibility of applying the ANN approach to decision-making in pedestrian flows.

Introduction

To cope with rapid population growth, increasing numbers of railway systems have been constructed across the world, ranging from high-speed railways such as the Eurostar in Europe to the more recent magnetic levitation trains such as the Shanghai airport train in China. The projected trend is that railway systems will continue to increase in size, and thus crowd movement and evacuation planning will play a more important role in railway systems than ever before. The Hong Kong transportation system is characterised by high passenger flows, a short train headway and limited capacity in the transportation stations. The failure of facilities inside a station may cause accidents and threaten passengers' lives. A study of route choice between escalators and stairways in subway stations in Hong Kong was carried out [1] to explore the optimisation of station facilities, which is critical for both safety and operational efficiency.

In the past three decades, several dynamic evacuation and pedestrian models have been developed for modelling complex crowd movements. These models include social force (SF) models [2], cellular automata (CA) models [3], lattice gas (LG) models [4], fluid-dynamic model [5], agent-based (AB) models [6] and SGEM model [7,8]. They provide important information about the spatial design of complex buildings, underground stations and other public amenities. In addition to these microscopic [2–4,6–8] and macroscopic models [5], network models [9,10] have proved useful in the design of emergency evacuation plans, because they allow the detailed modelling of human cognitive processes. However, most of the existing pedestrian flow models that simulate the dynamic movement of pedestrians are based on mathematical models, which may not be able to sufficiently mimic actual human behaviour. Indeed, the movement decisions that are obtained by these models are determined by either empirical equations (e.g., Bradley [5] employed Navier–Stokes equations that govern fluid motion to describe crowd movement at high densities) or by assumptions (e.g., the SF models [2], CA models [3], and LG models [4] treat individuals or groups as homogeneous, and do not consider heterogeneous human behaviour such as herding). Even with AB models such as Simulex [11] and buildingEXODUS [12], occupant behaviour is assigned by the operator according to his or her preference, and the resultant simulated pedestrian flow patterns may not reflect real-life situations.

One of the critical behavioural reactions of humans during evacuation and in moving crowds is route choice. Route choice is influenced by many factors, including personal experience, building geometry, interactions among occupants and environmental factors [8,12,13]. In general, passengers will choose the path with the shortest travel time, travel distance or a combination of both [14]. However, Proulx [15] pointed out that evacuees tend to prefer familiar routes rather than the shortest path to the exit, because they feel that unknown paths increase the threat. Proulx's pioneering work depicted the complexity of route choice in human movement. Gwynne et al. [12] proposed an exit selection behaviour model that is based on "Queuing and Familiarity Behaviour". Lo et al. [8] introduced a game theory based exit selection model for evacuation. Hoogendoorn and Bovy [16] proposed a new theory of pedestrian route choice behaviour under uncertainty based on the concept of "utility maximisation".

These route choice models all use mathematics to simulate the human decision-making. In contrast, this paper proposes the alternative approach of applying an ANN model to capture human decision-making behaviour by data collected from actual passengers.

Route choice behaviour on escalators

In transportation stations, escalators, stairways and elevators serve as vertical transport between the concourse and the platforms. Passengers tend to use escalators rather than stairs or lifts. They avoid climbing stairs to save energy and avoid spending time waiting for lifts. Escalators play an important role in transportation

* Corresponding author. Tel.: +852 3442 2307; fax: +852 2788 7612.
E-mail addresses: kakuiyuen2-c@my.cityu.edu.hk, ericlee@cityu.edu.hk (J.K.K. Yuen).

http://dx.doi.org/10.1016/j.asoc.2014.05.031
1568-4946/

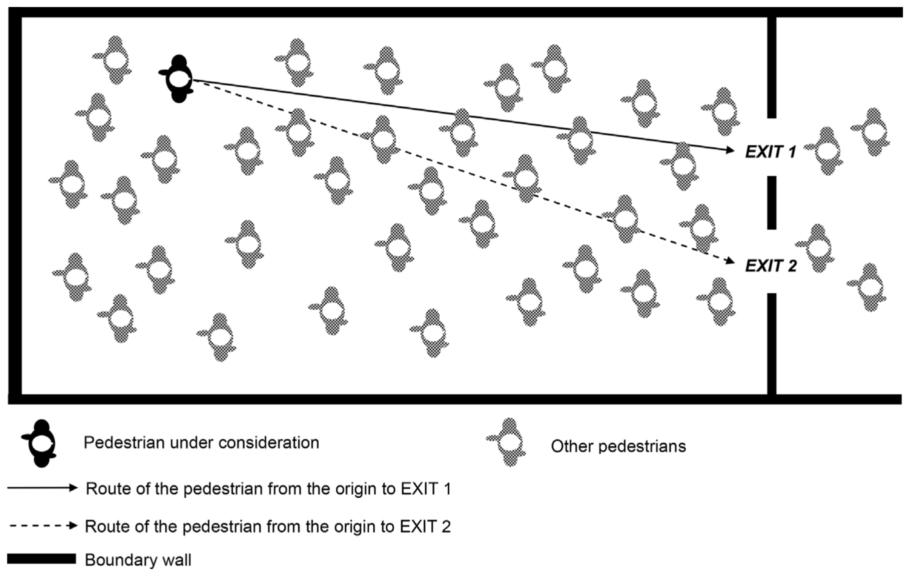

Fig. 1. Example of routes choice decision-making.

around a station. Optimising the use of escalators is thus the first priority in the internal transportation system of stations.

This study presents an example of route choice in a transportation station. Passengers approach two escalators and choose one of them to travel to the upper floor. The decision-making involves the consideration of various factors, which are explored in the following sections.

Routes choice behaviour

Initial research in this area [17,18] focused on the correlation between throughput capacity and the width of exits. Fig. 1 shows the layout of a compartment with two exits. In an emergency (e.g., the outbreak of fire), each occupant inside the compartment will choose one of the exits to leave the compartment. This is a typical example of route choice decision-making. In predicting the evacuation time from the origin of an evacuee to the exit of the compartment, Togawa [18] established empirically that the evacuation time T_e can be expressed as a sum of the flow time (T_o) and the travel time (T_f) of the evacuee as follows.

$$T_e = T_o + T_f \tag{1}$$

In the simplest form, T_o can be further expressed in Eq. (2), where k_s is the distance from the point of the evacuee to the destination, and v represents the walking speed of the crowd.

$$T_o = \frac{k_s}{v} \tag{2}$$

The travel time T_f is estimated by Eq. (3), where N_a is the total number of evacuees, f_p' represents the flow rate per unit width of the exit and B' is the width of the exit.

$$T_f = \frac{N_a}{f_p' B'} \tag{3}$$

Usually, pedestrians choose the route with the least travelling time. According to Togawa [18], the factors that contribute to the travelling time are as follows.

1. The walking velocity of the pedestrian.
2. The distance from the origin of the pedestrian to the exit.
3. The maximum flow capacities of the exits.

These factors form the basis of this study to investigate the parameters in human route choice decision-making for ANN model training.

The remainder of this paper is organised as follows. Section “Artificial neural network” introduces the ANN for route choice in moving crowds. Section “Data collection” discusses how the data was collected from the transportation station. Section “Development of the MLP model” outlines the development and architecture of the ANN model. Sections “Model training” and “Results and discussion”, respectively, present the model training process and evaluate the performance of the ANN model. Section “Conclusion” concludes the paper.

Artificial neural network

ANN models have developed rapidly in the last few decades, to the extent that they are now able to mimic the correlation of system parameters that are unknown or complex [19] and capture the nonlinear behaviour of a system via a “learning” process (also known as the “training” of the network function) from historical system data. ANN models have also become a popular approach to the prediction of non-linear functions in the past decade. Among the various ANN models, the multi-layered perceptron (MLP) [20] is one of the most widely used for forecasting due to its simple and flexible nature. MLP has been successfully used to predict the weather, flank wear in drills and thermal load predictions [21–26]. However, researchers have seldom applied ANN models to simulate pedestrian decision-making in moving crowds or evacuation planning due to the extensive resources required for the data collection and pre-processing.

One of the merits of ANN models is that they do not require highly specialised human expertise nor any assumptions. The learning feature of ANN models is especially useful for human decision models, as the relationships between the input parameters are less well known than in highly structured expert systems or equation-base approaches [19]. In this study, the MLP is adopted to predict route choice in pedestrian flows.

Data collection

The data was collected from a transportation station in Hong Kong. A bank of escalators inside the station, as shown in Fig. 2, was offered by the transportation company for the study. There are three escalators, one of which had been stopped to save energy. The other two escalators were moving upward at an equal and constant speed. The passenger flow was unidirectional. All passengers are required to ascend to the upper floor via escalator to leave the station. Passengers approaching the escalators have to choose one of the two escalators to ride to the upper floor. This is the decision making that is investigated and mimicked by the MLP model.

It is normal practice in Hong Kong, as in some other countries, for passengers not in a hurry to stand on one side of the escalator and leave the other side for passengers in a hurry to walk up to shorten the time spent riding the escalator. Both of the escalators shown in Fig. 2 are 60 m long. This long length prevents most