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RESEARCH PAPER

Simulation of Passenger Flows on Urban Rail Transit Platform based on Adaptive Agents

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Abstract: Modeling and simulation of passenger flows on urban rail transit platform is a key issue in improving operation efficiency and service of level of urban rail transit, which should consider architectural environment, facilities implementation, and transportation organization. To simulate this kind of passenger for planning or evaluation, 3-layer architecture adaptive agent model is proposed to simulate passenger microscopic behaviors, which is based on visual perception module, making-decisions module, and action execution module. In respect of perception of agents, we construct a neuron-model-based perception model of environmental crowding to examine how individual URT passengers on the move represent the visual information of environmental crowding. Then, we define rules for behaviors based on cognitive heuristics for making-decisions module, and propose a discrete rule for the updating of passenger movement state for action execution module. Based on modeling passenger behavior dynamics, a microscopic simulation model for complex passenger flows on urban rail transit platform is developed. As a case study, the passenger flows scenarios of an island platform of urban rail transit station are simulated. Simulation results show that boarding and alighting passengers demand and train departure frequency have a remarkable impact on the maximum number of assembling passengers on platform and efficiency of mustering and evacuating under given conditions of building environment and facilities.

Key Words: urban traffic; urban rail transit; microscopic behavior model; adaptive agents; passenger mustering and evacuating simulation; crowding perception modeling

1 Introduction

The mustering and evacuating behaviors of passengers on urban rail transit (URT) platforms, where the passengers directly interact with the URT system, are characterized by significant complexity, nonlinearity, and dynamics. This leads to declined efficiency of passenger movement and directly impacts the operating efficiency and level of service that URT system can offer. Therefore, studying the mustering and evacuating phenomena of passenger flows on URT platforms is important for the operating organization and safety.

Giving full play to the network effect of URT is dependent on the coordination and cooperation between operating organization and architectural environment. Once infrastructures are completed after absorbing huge investment and extended time of construction, their unreasonable arrangements, if any, can hardly be improved. This is why researchers have attached more attention on coordinating the design of the interaction between the architectural environment of stations and the passengers. Examples include zone-specific level of service evaluation [1, 2], effect of the configuration and arrangement of facilities and equipment on passenger mustering and evacuating behaviors [3, 4], analysis on the evacuation capability and bottleneck of facilities and equipment [5, 6], zone-specific self-organization phenomena of complex passenger flows [7-8], and effect of transport organization on passenger mustering and evacuating behaviors[9]. However, URT lines and networks may grow to such a scale that the complex requirements of passenger flows induced by their network effect cannot be satisfied by purely increasing the scale and capability of the facilities and equipment. As such, crowding platforms would become

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normal. It is necessary to not only comprehensively examine how the movement behaviors of passengers would be affected by the architectural environment, as well as the configuration and arrangement of facilities and equipment, and the transport organization; but also analyze the temporal-spatial patterns of passenger mustering and evacuating on platforms, and study the critical issues such as improving movement efficiency of passengers.

To address the aforesaid issues, this paper develops an adaptive agent-based model to simulate and calculate how URT passengers move and distribute on the platforms. It studies the internal mechanism whereby complex phenomena emerge from simple rules, and the temporal and spatial evolution patterns of macro passenger flows caused by local behavioral interaction of passengers in typical platform environments.

2 Crowding perception model of passengers on URT platform

2.1 Adaptive agent model

An agent is an artificial intelligence program having learning ability. An adaptive agent perceives changes to the surrounding environment, and continuously adjusts its internal state and adapt to such changes using cognitive results. To construct the simulation model of passenger mustering and evacuating behaviors on URT platforms, an adaptive passenger agent is defined as follows

$$P_i := < S, \Xi, \Psi, Z >_i \tag{1}$$

where, i is a pedestrian agent number, $i = 1,2,\cdots,N$; S is a set of pedestrian state variables; Ξ is the perception function, which analyses the visual information acquired by pedestrians; Ψ is the decision-making module of pedestrian walking behavior; Z is in charge of implementing the socially accepted decision made by a pedestrian by updating its state variables. It indicates changes to the movement state of a pedestrian agent; S consists of the variables representing passenger movement characteristics and the state values of these variables. Its definition is

$$S_i(t) := < \boldsymbol{x}, \boldsymbol{v}, v^0, m, T >_i \tag{2}$$

where, t is time of simulation; $\boldsymbol{x}$ is position vector; $\boldsymbol{v}$ is velocity vector; v^0 is expected velocity; m is mass of the passenger; Formula m /160[10] gives the radius of the passenger's projection on a horizontal plane; T is target point.

2.2 Crowding perception model

Crowding perception modeling involves a perception system whereby a passenger obtains information about his/her surrounding environment before the information is processed, filtered, and represented to obtain critical data that affects his or her decision-making. Existing studies [11] indicate that a moving pedestrian primarily obtains perceptive information through vision. To represent the visual information of the passenger, a discrete visual field of the passenger is shown in Fig. 1. The passenger's field of vision is identified by viewing distance H and viewing angle 2φ. α^0 is the angle between the passenger's movement direction and target point T.

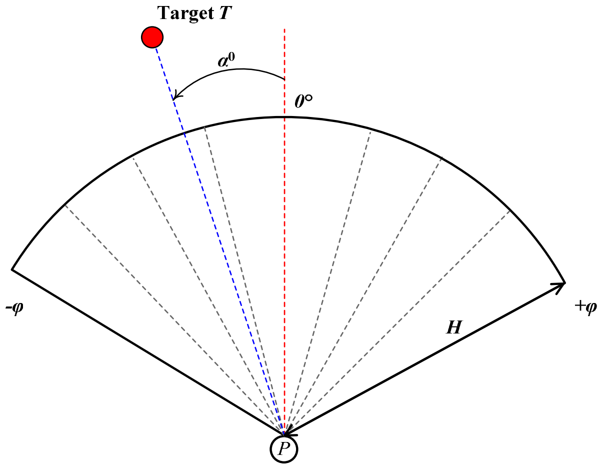

Fig. 1 The basic geometrical elements of passenger visual field

The passenger's movement behavior is significantly affected by visual information. Existing studies [12] indicate that a moving pedestrian avoids collision by estimating the time to take for him or her to collide with any other pedestrian or obstacle in the surrounding. In addition, the passenger's perceptive ability and cognitive process are affected by the surrounding environment; that is, his or her representation of visual information is dependent on his or her perception of the crowding in the environment. Our model represents the passenger's visual information based on the representation method of visual information proposed by Moussaïd [13], as shown in formula (3)

$$d_{\text{mental}}(u, \alpha) = f(u) \cdot d_{\text{physical}}(\alpha) \tag{3}$$

where, $d_{\text{mental}}(u, \alpha)$ is the mental distance away from another passenger or obstacle whom or which the passenger perceives to first collide with in any direction α within his/her field of vision; $d_{\text{physical}}(\alpha)$ is the physical distance to the first collision within pedestrian visual field. Note that if no collision is expected to occur in direction α; $d_{\text{physical}}(\alpha)$ is set to a default maximum value $d_{\max}$, which represents the view distance H of pedestrian. The function of perception u sums the primarily perceived visual information inputs to assess the crowding degree of walking condition; $f(u)$ is the sigmoid function applied to activate the value u. This sigmoid function simulates pedestrian perception that saturates in cases where a higher local density occurs. It can be reflected by the formulas(4)-(7).

$$f(u) = \frac{1}{1 + e^{-u}} \tag{4}$$

$$u = \sum_{k=1}^{8} \omega_k \cdot \phi_k - \theta \tag{5}$$