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Information guiding effect of Evacuation Assistants in a two-channel segregation process using Multi-Information Communication Field Model

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ABSTRACT

In the present work, a Multi-Information Communication Field Model is proposed, which accurately describes the processes for which an Evacuation Assistant disseminates the information of each exit route using the strategy and evacuees receive, cognize and react to the multi-information. The information's influence and Evacuation Assistant's dynamic adjustment guiding strategy according to the crowd's exit selection are highlighted. The effectiveness of the Evacuation Assistant's guiding strategy and its influence factors, such as Evacuation Assistant's sensing radius, evacuees' prior exit preference and cognitive inertia, are considered and fully discussed. The simulations of crowd's segregation process were performed in a T-shaped channel scenario and the conclusions indicated that the Evacuation Assistant's guiding effect will be insufficient, optimum, or excessive for different sensing radius values, a larger sensing radius is not necessarily better, and the appropriate sensing radius could help the Evacuation Assistant achieve the segregation target. When the segregation target, the speed of the evacuees, and the evacuees' exit preference vary, the sensing range should be changed accordingly. And the optimal sensing radius and its changing law were presented as well.

1. Introduction

During crowd emergency evacuation in large public buildings, making full use of escape routes through segregation of the crowd is conducive to achieving the shortest evacuation time. Most of the modern buildings have large room capacities and functional diversity, and these features would lead to the result that the evacuation route is long or complex. If some of those known escape routes were blocked due to the destructive incident, it will be extremely urgent to disseminate the right route information and guide the crowd dynamically. Information guiding is always a key to a successful building evacuation during an emergency, which has been stressed repeatedly by human behavior experts that information is needed for occupants to make timely decisions. By providing information through signage, audio broadcasting and Evacuation Assistants, people can refine their situation awareness, making them more competent at weighing their options before engaging in proper actions (Fahy and Proulx, 2009). However, due to the panic situation and various crowd characteristics, the effectiveness of guiding behavior and intervention strategy should be fully discussed.

Emergency evacuation indication system which consists of guiding devices showing the fixed direction and exit sign devices are commonly and widely used for indicating information. The availability of these devices is very relevant with their physical properties (Collins et al., 1993; Wong and Lo, 2007; Jeon and Hong, 2009) and the architectural structure characteristics. O'Neill (1991) pointed out that emergency signages could not solve the path finding problem brought by the complexity of floor plan configuration. The signages on the ceiling (Kobes et al., 2010) or blocked by the shelves (Horasan, 1999) are hardly detected by evacuees. Thus, the signages may not give full play to the role of evacuation instruction. By contrast, studies of evacuation behavior from aircraft (Muir and Thomas, 2003, 2004) demonstrated that leader figures, as information senders – either from the authorities or from within the crowd itself – play an important role in enhancing efficiency, and communication and information were vital (Dyer et al., 2008). In addition, the panic theories showed that well-trained Evacuation Assistants (EAs) (or trained staffs) would present as a strong positive social influence and could help calm

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Nomenclature

$E(n)$	building exit with a serial number of n
$S_{(x,y)}^{E(n)}$	the value of SFF in position (x, y) describing the shortest route information with $E(n)$'s position as the destination
$k_S^{E(n)}$	the parameter of SFF describing evacuee's escape speed
$k_M^{E(n)}$	escape motivation towards $E(n)$
$k_I^{E(n)}(t)$	knowledge of escape route towards $E(n)$
t	time step
P_{x_1,y_1}	the transition probability that evacuees or EAs move to a neighboring cell (x_1, y_1)
ω	target segregation proportion
ω'	final actual segregation proportion
σ	evacuee's priori exit preference describing the proportion of evacuees who preselected the preferred exit to escape
R	EA's sensing radius
$C_{(x,y)}^{E(n)}$	information particle at position (x, y) containing the shortest route information with $E(n)$'s position as the destination
$N_C^{E(n)}$	number of $C_{(x,y)}^{E(n)}$ dropped by EAs
$\alpha_C^{E(n)}$	diffusion probability of $C^{E(n)}$
$\delta_C^{E(n)}$	decay probability of $C^{E(n)}$

Abbreviations

EA	Evacuation Assistant
CA	cellular automata
SFF	static floor field
CF	communication field (model)
MICF	Multi-Information Communication Field (Model)

people's panic and irrational action (Pan et al., 2006). Based on the well-known knowledge that perception can drive behavior (Hall, 2004), the relationships among emergency information processing, decision making and movement need to be researched and better understood (Shields et al., 2009).

Guiding the crowd towards a safe direction and leading their movement through voice commands and gestures are the two main intervention approaches of EAs that affect the exit selection process of the evacuees (Hayashi, 1988; Sugiman and Misumi, 1988). Sugiman and Misumi (1988) defined the two approaches as Follow Directions method, which was a traditional method that EAs indicate the direction of an appropriate exit for as many persons as possible with a loud voice and vigorous gestures, and the Follow Me method, which showed that each EA individually asked the evacuees who were closest to follow the EA and led them to the appropriate exit. In current modeling studies, EA's leading behavior was usually described by the following behavior of evacuees to EAs. Essentially, an EA with leading behavior will transmit route information indirectly through his moving direction. The effect of leadership on crowd dynamics was limited by many factors, such as the relative speeds and positions of the EAs and the crowd (Aubé and Shield, 2004), EA's number and position arrangement (Hou et al., 2014) and the visual range of each evacuee (Yuan and Tan, 2009, 2011). In contrast, the guiding behavior, which is the way of directly transmitting route information, may deserve more attention.

Considering information guiding effect, the current researches are still preliminary. The human blindfolded tests were conducted to study the influence of information transmitted by sound on the individual's route choice behavior (Yang et al., 2009, 2012). The results demonstrated that spatial distance information can reduce the evacuation time. Henein and White (2010) built the communication method of providing spatial route map between agents, such as a physical pushing force, and found that communication increased both exit rates and crowd safety. Pelechano and Badler (2006) simulated crowd movement based on the social force model. In their model, the duty of EAs was sharing their knowledge about the environment with other agents they meet during the escape process, and a significant improvement on evacuation efficiency was shown. Braglia et al. (2013) proposed an evacuation simulation model incorporating a new game theory of multistage games with perfect information, which showed the evacuees' exit selection process that is affected by the presence of the egress coordinator (a sort of leader). The conclusions demonstrated that the instructor staff are very important and effective in order to improve the safety of the evacuation. In the proposed game theory based model, an agent will follow the suggestions of egress coordinator if he is close enough to the egress coordinator and/or his anarchy is sufficiently small. And with perfect information, all players know the game structure, and when making an decision, each player is perfectly informed of all the events that have previously occurred. This basic assumption actually does not meet the real decision-making process of evacuees during the emergency evacuation. Furthermore, the effect of egress coordinator is obviously influenced by the distance between he and the agents. However, due to the crowd's classic evacuation behaviors of herding and kin behavior, the exit information and the leader will actually affect the crowd in a range far beyond the leader's sound travel distance. In our previous work, the Follow Directions method and EA's guiding behavior were performed by communication field (CF) model (Wang et al., 2012). The effect of escape information upon evacuees was reflected in a dynamic process via an increased knowledge of routes, which shows evacuee's psychological cognitive processes. But CF model cannot describe the mechanism of multi-route information transmission and its effects. In emergency situations, evacuees guided by EAs would be required to segregate into different groups according to an efficient evacuation route planning. However, the segregation results would be fluctuating because EAs' personal perception ability and event handling capability are limited. Therefore, it is significant to explor the factors influencing the segregate results by modeling the information transmission and EA's action on the evacuee's movements.

In the present work, a Multi-Information Communication Field Model (MICF) is proposed, which describes the processes of an EA disseminating multi-route information using a certain strategy to affect the evacuees' exit selection and of evacuees receiving, cognizing and reacting to the information. Based on an assumed information feedback mechanism, EA's dynamic adjustment guiding strategy according to the crowd's exit selection is highlighted, and the effectiveness of the guiding strategy and its influence factors, such as EA's sensing radius, evacuees' prior exit preference and cognitive inertia, are considered and fully discussed.

2. Multi-Information Communication Field Model (MICF)

The CF model for describing EAs (Wang et al., 2012) was generated using CA and the floor field. The CF was inspired by the dynamic floor field (DFF), which is similar to the pheromone field of the ant-trail model, and describes pedestrians' walking track and herding behavior through pedestrians being attracted by bosons dropped by others. In the CF model, similarly, EAs drop information particles, which constitute the CF, to transmit escape