Physica A 390 (2011) 1042–1050

Contents lists available at ScienceDirect

Physica A

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

Conflict game in evacuation process: A study combining Cellular Automata model

Xiaoping Zheng*, Yuan Cheng

Institute of Safety Management, Beijing University of Chemical Technology, Beijing 100029, China

ARTICLE INFO

Article history:
Received 3 October 2010
Received in revised form 29 November 2010
Available online 15 December 2010

Keywords:
Conflicts in evacuation
Rationality
Herding
Evacuation time

ABSTRACT

The game-theoretic approach is an essential tool in the research of conflicts of human behaviors. The aim of this study is to research crowd dynamic conflicts during evacuation processes. By combining a conflict game with a Cellular Automata model, the following factors such as rationality, herding effect and conflict cost are taken into the research on frequency of each strategy of evacuees, and evacuation time. Results from Monte Carlo simulations show that (i) in an emergency condition, rationality leads to "vying" behaviors and inhibited "polite" behavior; (ii) high herding causes a crowd of high rationality (especially in normal circumstances) to become more "vying" in behavior; (iii) the high-rationality crowd is shown to spend more evacuation time than a low-rationality crowd in emergency situations. This study provides a new perspective to understand conflicts in evacuation processes as well as the rationality of evacuees.

© 2010 Elsevier B.V. All rights reserved.

1. Introduction

In the process of emergency evacuation, people often resort to conflict when seeking a better position at bottleneck. Former research of crowd conflicts is based on microscopic dynamics models, including the continuous space model [1–3] and the discrete space model [4–7]. Until now, most studies have been content to reproduce conflict behavior by introducing some kind of friction [1] and/or friction parameter in the sense of probability [6]. As for the process of formation of conflicts and the essential mechanism of the conflicts, further investigation is needed.

Game theory is acknowledged as a tool for interpreting conflict problems, and it promises well as a useful approach to study crowd evacuation [8]. To date, the existing models for evacuation are based on classical game-theoretic framework. Lo et al. [9] proposed a dynamic exit selection model by calculating a mixed-strategy Nash equilibrium of a zero-sum game. The work of Hoogendoorn and Bovy [10] was on the route-choice model for pedestrians by using a differential dynamical game based on individual utility function. Although many researchers claimed that the competitive behaviors [7] and the rationality problem of evacuees [11] would have been interpreted in a game-theoretic way, very few studies on game theory have been conducted to explore crowd conflict behaviors in the process of evacuation. The purpose of the present research is to investigate crowd conflicts in the evacuation process and the related mechanisms of the formation of conflicts by using conflict game, and for demonstration of the whole process of evacuation, with a Cellular Automata (CA) model of crowd dynamics.

* Corresponding address: Institute of Safety Management, Beijing University of Chemical Technology, Mail Box 17, No.15, Bei San Huan East-Road, ChaoYang District, Beijing 100029, China. Tel.: +86 10 64426585; fax: +86 10 64412837.

E-mail address: asean@vip.163.com (X. Zheng).

0378-4371/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.physa.2010.12.007

	Polite	Vying
Polite	0,0	0,b
Vying	b,0	-c,-c

Fig. 1. The two-player conflict game with two strategies.

	Polite	Normal	Vying
Polite	0,0	0,b	0,b
Normal	b,0	b/2,b/2	0,b
Vying	b,0	b,0	-c,-c

Fig. 2. Two-players conflict game with three strategies.

2. Model

2.1. Conflict game in evacuation

The crowd conflicts in evacuation bear a close analogy to the Chicken-type game. Suppose that the scene is an exit, for which only one person can get through at one time. Furthermore, suppose two persons are seeking to escape from the exit as soon as possible. Each of them has two strategies: "vying" or "polite". The above scene can be described in terms of 2×2 games as shown in Fig. 1. If the two persons are both vying for the exit, neither of them will get through the exit, and the corresponding payoffs for them are both P $(-c)$ due to the cost of their effort to vie. If the two persons are both polite, they will remain still and their payoffs are both $R(0)$. Should one person chose vying and the other, polite, the vying person will get through the exit and obtain $T(b)$, while the polite one's benefit is $S(0)$. The payoff has the following relationship: $T > S = R > P$.

During evacuation, a jamming often occurs at the bottleneck due to ramped vying in a large crowd for the unique, narrow exit. Besides "polite" and "vying" strategies, the more common strategy "normal" should be introduced into this model as well. "Normal" strategy means the person adopts the strategy that is neither vying nor polite, indicating the person is escaping in order. Thus, this research presents a game-theoretic model as $G = \langle N, A, U\rangle$, where $N = \{1, 2, \ldots, n\}$ denotes the players, $A = \{\text{“Polite”}, \text{“Normal”}, \text{“Vying”}\}$ denotes strategy sets, and $U = \{u_1, u_2, \ldots, u_n\}$ is a payoff function as follows.

For person $i \in N$, the payoff function $u_i : A^n \to R$ can be written as

$$u_i(a_i, a_{-i}) = \begin{cases} 0, & \text{if } h_V(a) = 0 \text{ and } h_N(a) = 0, \\ b/h_N(a_i, a_{-i}) \cdot I_N(a_i), & \text{if } h_V(a) = 0 \text{ and } h_N(a) > 0, \\ b \cdot I_V(a_i), & \text{if } h_V(a) = 1, \\ -c \cdot I_V(a_i), & \text{if } h_V(a) > 1 \end{cases}$$

where $h_V(a)$ and $h_N(a)$ denote the number of persons who chose to be "vying" and "normal" respectively, and $I_y(x)$ is an indicator function, such that $I_y(x) = 1$ for $x = y$ and is zero elsewhere. The definition of the payoff function above seeks to provide the following facts. "Polite" persons obtain the value, 0, being they chose to stay still. "Vying" persons who ultimately attain the position, get the payoff, b, while "vying" persons who fail to attain the position pay the cost, c. For the crowd only, including "polite" and "normal" persons, the "normal" persons are able to obtain the position with equal probability, so the payoff is an expectation of the benefit in a sense of probability.

Let us consider the following example: a 2×3 (two-player, three-strategy) game defined in Fig. 2. It is straightforward to obtain pure Nash equilibria of the game as follows: ("Polite", "Vying"), ("Vying", "Polite"), ("Normal", "Vying"), and ("Vying", "Normal"). Like the Chicken-type game, the equilibrium is alternating reciprocity. Another mixed-strategy Nash equilibrium is $(0, 2c/(2c + b), b/(2c + b))$, which is the probability over the strategies, "polite", "normal", and "vying". During an infinite population game, the mixed solution indicates the frequency of each strategy. When the cost, c, approaches to 0, the corresponding mixed-strategy solution is $(0, 0, 1)$, which means all the persons in the game adopt to be "vying"; when the cost c is sufficiently large, the solution is $(0, 1, 0)$, indicating all the persons are "normal". In addition, although ("Normal", "Normal") is not the pure Nash equilibrium solution, it may be interpreted as a cooperation reciprocity. For each round in the game, either side can obtains payoff, $b/2$ by adopting the ("Normal", "Normal") solution, which is equal to the value of the alternating case in the sense of the sum of both players.

Download English Version:

https://daneshyari.com/en/article/10481173

Download Persian Version:

https://daneshyari.com/article/10481173

Daneshyari.com