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A NEW MODELING OF THE PEDESTRIANS EVACUATION IN PANIC SITUATIONS BASED ON VICSEK MODEL

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ABSTRACT

Nowadays, evacuation problem is critical since it is used in many applications. These applications include sites where masses of people gather such as sporting events, transportation centers, and concerts. A relevant objective is how to consider the mobility of pedestrians in a room in order to improve evacuation times. In this paper, we realistically simulate how human communication affects the behavior of individuals' pedestrians using a modified Vicsek model. The considered modifications of the original model are achieved by introducing more features and parameters into the original model. The simulation results show that evacuation time is greatly affected by several factors, such as, number of pedestrians (density), the panic situation and the chance to find an appropriate exit and escape paths

Keywords: *Evacuation, mobility pedestrians, panic situation, vicsek model, discrete and continuous-space*

1. INTRODUCTION

Pedestrians' evacuation from large and complex building is usually hindered by people not knowing its detailed internal connectivity. In such circumstances, occupants might not be aware of the existence of suitable circulation paths or, in the case of emergencies, the most appropriate exists and escape paths.

Recently, a considerable amount of research has been done for simulating the local motion of individuals in a crowd of pedestrians in the street or people finding their way inside a building or a room [1-7]. Such models can be broadly separated into two categories: (1) discrete-space models and (2) continuous-space ones. Discrete-space, or cellular automata-based, models allow pedestrians to be located at nodes of a fixed grid, and pedestrian coordinates are updated at discrete time intervals. Particular models of this category are described in Chen X and al [1]; Bierlaire M. and al [2]; Schadschneider [3]; Blue and Adler [4]; Dijkstra, Jesurun, and Timmermans [5]; Kessel and al. [6]; and Batty, DeSyllas, and Duxbury [7]. Continuous models on the other hand allow pedestrians to move continuously in a 2-D surface representing a street, a room, and so forth. The continuous-space models in turn can be subdivided into many groups. Some models, such as the ones considered in Helbing [8] and AlGadhi, Mahmassani, and Herman [9], are based on a similarity between the dynamics of a crowd and that of a fluid or gas. Other models allow pedestrians to choose their paths by optimizing a certain cost function [10]. An interesting model combining the fluid dynamics approach with that of a cost function is considered in Hughes [11]. Finally, the model considered in other sources [12-13] introduces social and physical forces among pedestrians and then treats each pedestrian as a particle abiding the laws of Newtonian mechanics.

The aim of this paper is to study the overall evacuation times from a room where individuals move according to Vicsek model with or without a panic situation. This paper is organized as follows. The description of Vicsek model is presented in section 2. Section 3 discusses two rules added to basic Vicsek model. These rules reflect the panic situation and the chance to find an appropriate exit door or escape path. In section 4, results of the simulation are presented and discussed in detail. Finally, conclusion and future work are given in section 5.

2. BASIC VICSEK MODEL: AN OVERVIEW

The Vicsek model was introduced in 1995 by T. Vicsek et al. [14]. The aim is to formulate a minimal model of collective leaderless movement. In this model, n particles move within a 2D box of sides L with periodic boundary conditions. The particles are characterized by their positions, $x_1(t)$, . . . , $x_n(t)$, and their velocities $v1(t) = v_0 e^{-i\theta_1(t)}$, . . . , $v_n(t) = v_0 e^{-i\theta_n(t)}$, (represented here as complex numbers). Initially all particles are randomly distributed in space with directions identified by the angles $\theta_n(t)$ chosen randomly. All the particles move with the same speed v_0. However, the direction of motion $\theta_n(t)$ of each particle changes in time according to a rule that captures in a qualitative way the interactions between organisms in a flock. The basic idea is that each particle moves in the average direction of motion of the particles surrounding it, plus some noise. To state these rules mathematically, we need some definitions. Let $R_n(r)$ be the circular vicinity of radius r centered at $x_n(t)$, and $K_n(t)$ be the number of particles whose positions are within $R_n(r)$ at time t. We will denote as $U_n(t)$ the average velocity of the particles which at time t are within the vicinity $R_n(r)$, namely:

$$U_n(t) = \frac{1}{K_n(t)} \sum_{j\ for\ x_j(t) \epsilon R_n(r)} v_j(t) \qquad (1)$$

With the above definitions, the interaction rule originally proposed by Vicsek et al. can be written as:

$$\theta_n(t+\Delta t) = Angle(U_n(t)) + \eta \xi_n(t) \qquad (2)$$
$$v_n(t+\Delta t) = v_0 e^{i\theta_n(t+\Delta t)} \qquad (3)$$
$$x_n(t+\Delta t) = x_n(t) + v_n(t+\Delta t)\Delta t \qquad (4)$$

Where $\xi_n(t)$ is a random variable uniformly distributed in the interval [-π , π], and the noise amplitude η is a parameter taking a constant value in [0,1]. The "Angle" function is defined in such a way that if u = $v_0 e^{i\theta}$, then Angle[u] =θ.

3. THE PROPOSED MODEL

In the basic Vicsek model, at every iteration, a person moves according to rules given in equation (1), (2), (3) and (4). However, in real life situations, a person may panic, and therefore remains in his place, even if he is able to move. This behavior is very important to model since the panic of an individual can be a kind of obstacles preventing other people to leave the building. On the other hand, there is no guarantee that a person who has reached the end of the room can find an exit door. An individual, in this case, is obliged to go around looking for another exit. To reflect this behavior, we introduce two rules:

- Rule1: A person is allowed to move according to Vicsek model, but, if he is in a panic situation, he remains in his place.
- Rule2: Not all persons reaching the border of the room are automatically evacuated.

To translate this, we introduce two probability $Proba_{evac}$ (Evacuation Probability) and $Proba_{panic}$ (Panic Probability). Thus, at each time step, a person is moved according to the Vicesk mobility model with probability $Proba_{panic}$ (Rule1). On the other hand, when an individual reaches the border of a room he is evacuated with a probability $Proba_{panic}$ (Rule2). These two rules can be written formally as:

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For each individual
If random > $Proba_{panic}$ then
    $x_n(t+\Delta t) = x_n(t) + v_n(t+\Delta t)\Delta t$
    If $Proba_{evac}$ > random then
    Evacuate the individual reaching the border of a room
    End if
End if
```

Algorithm 1: The two rules added to the basic Vicsek model

4. RESULTS AND ANALYSIS

Our goal is to propose a model that permits to study the evacuation performance when large groups of pedestrians using a Vicsek model try to find an escape path. The objective is to produce results that closely simulate real human behavior in these situations. This behavior includes especially motion by following the group and stress or panic situation.

The rest of this section presents the simulation results of the evacuation in a room comprising N (=500) mobile pedestrians distributed randomly in a square 2D room of sides L with periodic boundary conditions, i.e. the motion of pedestrians is running in a loop. The pedestrians move in the room according to the modified Vicsek model, presented in Section 3.

Each configuration is simulated for T=2000 time steps, of which the first half (1000 time steps) were discarded to let transients die out and for the system to reach its asymptotic steady state. The table 1 shows the parameters used in the simulation.

Table 1. Parameters Used In The Simulation

Parameter of the model	Value
Size of the room : L	50
Initial velocity : v_0	0.05
Interval Δt	1
Radius: r	1.0
Noise amplitude: η	$2*\pi*0.05$
Number of pedestrians : n	500

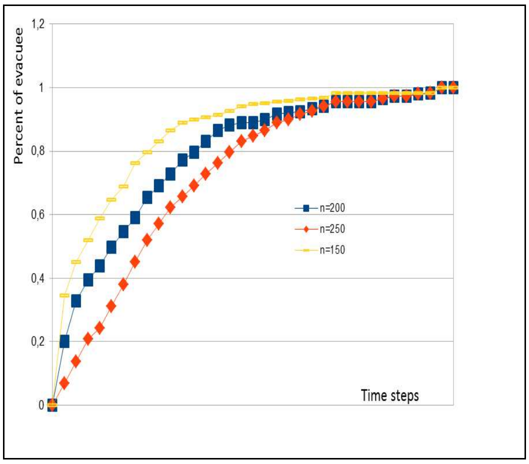

Figure 1. Percent Of Evacuated Pedestrians As Function Of Time Steps For Different Values Of The Number N Of Pedestrians.

In figure 1 we can readily observe different performances with different values of N. When the value of N decreases, the evacuation of 100 percent of individuals is reached earlier. Thus, the time required to evacuate 100 percent of individuals increases as the crowd size increases. This can be explained by the fact that for bigger crowd the probability of having congestion blocks at the exit doors increases, and consequently increases the evacuation time.

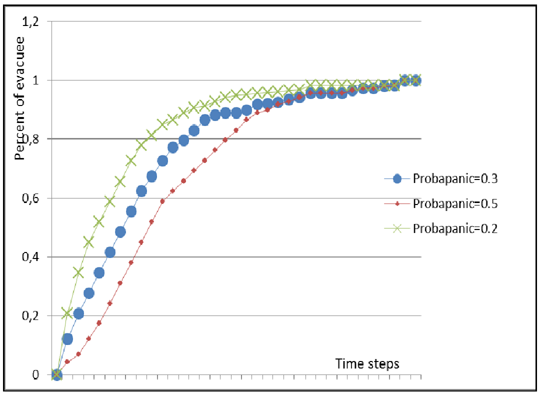

Figure 2. The Percent Of Evacuees As Function Of Time Steps For Different Values Of The Probability $Prob_{panic}$

Figure 2 shows the percent of evacuees for different values of the probability $Prob_{panic}$, representing the panic parameter. As expected, the percent of evacuees converges to 100 percent faster as the panic parameter decreases. This seems an obvious result given that a panic situation lead a pedestrian to rest in his place instead of moving towards an exit door (algorithm 1). The number of individuals reaching the border of the room is then reduced, and therefore the exiting the room.

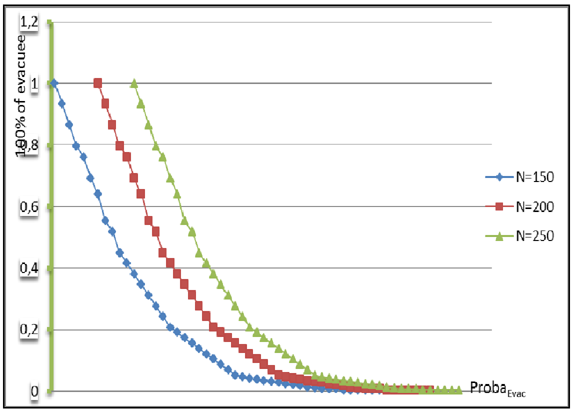

Figure 3. Time Of 100% Evacuee As Function Of The Probability Of Evacuation $Proba_{Evac}$. Each Curve Corresponds To N = 100, 150 And 200 Pedestrians Initially Distributed Randomly

Finally, figure 3 shows the time of 100% of evacuee as function of evacuation probability $Proba_{Evac}$. Different values of the number of pedestrians are considered. In the figure we notice that the overall evacuation time decreases as the values of $Proba_{Evac}$increases, eventually reaching a saturation state where further increases in the evacuation probability ($Proba_{Evac}$) does not have a major effects on evacuation time. This result is expected because more than the value of $Proba_{Evac}$is growing the individual is more likely to find an exit door or an appropriate escape pat

5. CONCLUSION AND FUTURE WORKS

In this paper we have proposed a Vicsek model based algorithm for the problem of evacuation of pedestrians from a room. The algorithm proposed used two additional rules to reflect real life situations, like panic situation and the chance to find an escape path. The simulation results show that evacuation time is greatly affected by several factors, such as, number of pedestrians, the panic situation and the chance to find an appropriate exit and escape paths.

In real life, some people have a higher probability of becoming leaders when an emergency occurs. They are usually independent individuals that by nature are able to handle emergency situations better and also tend to help others. These include security agent, regulars of the room, etc. Thus, in future work, we expect adding a leadership behavior to the basic Vicsek model, and applying it to this problem.

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