Physica A 392 (2013) 3329–3334

Contents lists available at SciVerse ScienceDirect

Physica A

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

Accelerating consensus of self-driven swarm via a weighted model

You Zou [a,*], Haifeng Zhang [b], Yujian Li [c], Binghong Wang [a,d]

[a] *Department of Modern Physics, University of Science and Technology of China, Hefei Anhui, 230026, PR China*
[b] *School of Mathematical Science, Anhui University, Hefei, 230039, PR China*
[c] *China Satellite Maritime Tracking and Control Department, Jiangyin, 214400, PR China*
[d] *Research Center for Complex System Science, University of Shanghai for Science and Technology, Shanghai, 200093, PR China*

HIGHLIGHTS

- A weighted self-driven swarm model is proposed.
- The impact of the neighbor on the center agent is determined on the view angle between them.
- There exists an optimal phenomenon leading to the shortest convergence time.
- The optimal phenomenon is robust to the density, the absolute velocity of swarms, and the strength of noise.

ARTICLE INFO

Article history:
Received 28 October 2011
Received in revised form 16 January 2013
Available online 10 April 2013

Keywords:
Vicsek model
Self-propelled agent system
Collective dynamics

ABSTRACT

In this paper, we study a weighted self-propelled agent system, wherein each agent's direction is affected by its spatial neighbors with different impacts. In the model, a tunable parameter $\alpha \geq 0$ is introduced to weight the different impacts of spatial neighbors: if $\alpha = 0$, the agent's direction is updated by averaging all of neighbors directions and own direction, i.e., Vicsek model. Otherwise, with the increase of the value of α, the agent's direction is more affected by the agent who has small view angle between them. Interestingly, simulation results show that there exists an optimal α leading to the shortest convergence time. Thus, our findings provide a powerful mechanism for collective motions in biological and technological multiagent systems.

1. Introduction

The collective motion is a ubiquitous phenomenon in the nature, ranging from the behavior of groups of ants, colonies of bacteria and clusters of cells in the microcosmic scale, to migration of flocks of birds and schools of fish in the macroscopical scale [1–9]. To understand the basic mechanism leading to the consensus of collective population, one prototypical model was proposed by Vicsek in 1995 [10] (labeled the Vicsek model). In the Vicsek model, N self-propelled agents are driven toward different directions with a constant absolute velocity in a squared zone with periodic boundary condition. Meanwhile, each agent synchronously updates its direction by averaging all directions of the agents within the horizon radius R of the agent (including the agent itself). The simple model shows that when the density of the system is high and the noise is small enough, all agents will converge to the same direction.

In recent years, due to simplicity and efficiency, many modified versions of the Vicsek model were proposed. For example, the models with adaptive velocities were proposed in Refs. [11–13]; the model with heterogeneous radii was introduced in

* Corresponding author. Tel.: +86 05513600157.
E-mail addresses: zouyouzy@mail.ustc.edu.cn (Y. Zou), haifeng3@mail.ustc.edu.cn (H. Zhang).

0378-4371/$ – see front matter
http://dx.doi.org/10.1016/j.physa.2013.03.060

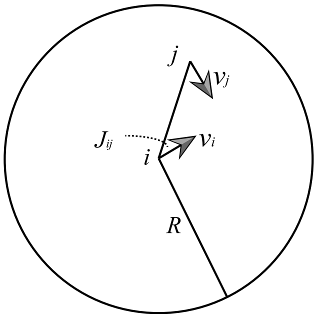

Fig. 1. The diagram of the model. J_{ij} denotes the view angle between agent i and its neighbor j.

Ref. [14]; a model with avoidance of collisions was studied in Ref. [15]; models with limited view angles were investigated in Refs. [16–20]. In addition, the models with effective leaderships were introduced in Refs. [21–24]. Most previous works, however, assumed that each agent updates its direction by averaging all agents' directions within certain scope. In reality, on one hand, most animals are incapable of seeing the neighbors following them. For example, the cyclopean retinal field of human is about 180° and the cyclopean retinal field of tawny owl is 201° [17,19]. On the other hand, when animals and persons are moving, the impacts of neighbors in front of the agent are often larger than the impacts of neighbors at side of the neighbors behind. Thus, to mimic such common phenomenon in the nature, in this paper, we propose a weighted self-propelled agent system, where the impact of a neighbor on the center agent depends on the view angle between them. The smaller view angle between them is, the larger impact of the neighbor on the center agent is. Extensive numerical simulations show that there exists an optimal phenomenon leading to the agents' direction consensus fastest. In addition, we find that such phenomenon is robust to the density, the absolute velocity of swarms, and the strength of noise.

The paper is organized as follows. The model is described in Section 2. The simulation results and qualitative analysis are given in Section 3. The work is concluded in the last section.

2. Model

In the original Vicsek model, the position of agent i is updated according to Refs. [10,25]

$$x_i(t+1) = x_i(t) + v e^{i\theta_i(t)}. \tag{1}$$

Here v is the absolute velocity, $\theta_i(t)$ is the direction of the movement. In addition, at time step t, each agent averages all the agents' directions within the horizon radius R of the agent (including itself) as its direction of time $t+1$, so its direction is updated as

$$e^{i\theta_i(t+1)} = e^{i\Delta\theta_i(t)} \frac{\sum\limits_{j\in\Gamma_i(t)} e^{i\theta_j(t)}}{\left\| \sum\limits_{j\in\Gamma_i(t)} e^{i\theta_j(t)} \right\|_2}. \tag{2}$$

Where $\Delta\theta_i$ denotes the noise of the system, and $\Gamma_i(t)$ is the set of neighbors for agent i at time step t (including itself).

From Eq. (2), we can find that, in the Vicsek model, the impacts of neighbors on the center agent are the same regardless of their locations or directions. As we mentioned, individuals may be easily affected by the neighbors in front of them. So, to reflect such fact, we first define the view angle between the agent i and one of its neighbor j, J_{ij}, which is the angle between the line individual j to i and velocity of individual i. The sketch of view angle is illustrated in Fig. 1.

The impact of the agent j on the center agent is given as the function of the view angle J_{ij}

$$W_{ji} = \frac{e^{-\alpha J_{ij}}}{\sum\limits_{j\in\Gamma_i(t)} e^{-\alpha J_{ij}}}. \tag{3}$$

α is a tunable parameter to adjust the different impacts of neighbors' directions on the center agent. The term $\sum_{j\in\Gamma_i(t)} e^{-\alpha J_{ij}}$ in the denominator of Eq. (3) is to normalize the impacts of different neighbors agents and itself. In this paper, we do not consider the case of $\alpha < 0$, because it means that agents are easily affected by the neighbors behind them, so it is somewhat irrational. $\alpha = 0$ means that the impacts of neighbors are equally considered, i.e., the Vicsek model. When $\alpha > 0$, the smaller view angle J_{ij} between agent i and neighbor j is, the larger impact of j on the next direction of agent i is. Namely,