An Effective Simple Shepherding Algorithm Suitable for Implementation to a Multi-mobile Robot System

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Abstract

In this paper, a simple and effective shepherding algorithm is presented. The shepherding is to guide or control a flocking behavior by one or more external agents which called shepherds. In general, a complex strategy is necessary for treating with a flock which has a lot of members. We propose a simple scheme using only simple rules like boid's rule proposed by C. Raynolds. Behavior of the shepherd is derived from only simple rules. The validity of the proposed method is confirmed for demonstrations a flock with a lot of members which is herded by single to two shepherds and the limitations are discussed. The computer simulations show that the proposed method is possible to control a flock with about 25 members by single shepherd and about 30 members by two shepherds. Furthermore, the autonomous cooperation for two shepherds can be generated by the proposed rules.

1. Introduction

Modeling and Simulating of flock behavior has been studied by many researchers in a variety fields such as robotics, control, biology etc.[4,5,6,7] Generally, complex theory is necessary to treat complex and unpredictable behaviors. A boid model, proposed by C. Raynolds, gave a break through against the problem.[1] In the model, complex behavior of a flock is well described by interaction between simple behaviors of individuals. After that, the boid model was used to realize coordinated animal motions by many researchers.

On the other hand, a shepherding is studied as one of flock behavior researches. The shepherding is to guide or control a flocking behavior by one or more external agents which called shepherds [2]. The shepherding is useful for a wide variety of fields. An effective method for shepherding has been studied by Lien et al., which can control flocks by skillful steering strategies using shepherd formations.[2,3]

We try to control flocks by more simple mechanism suitable for implementation to autonomous robots. The proposed shepherding mechanism is based on the reaction forces between individuals. Behavior of the shepherd is derived from simple mechanism based on the observable local information in real world applications. Only the direction which the flock is steered is given. In the computer simulation, absolute positions of all individuals are known. The assumption is hard to realize for real world problem. The proposed method uses only observable local information for action generation of individuals (includes shepherds) not uses absolute position information of all individuals. The validity of the proposed method is confirmed for demonstrations a flock with more than 25 members which is herded by single to two shepherds and the limitations are discussed.

2. Behavior rules for flock and shepherd

We assume a shepherding model which is to guide or control a flocking behavior with a lot of members by one or more external agents (called *shepherds*). As describing a flocking behavior, a well known model is the Boid which has been proposed by C. Raynolds in 1987[1]. The model describes realistically a complex behavior of a flock by only three simple rules as followings;

1) *Separation*: avoid collisions with neighbors or obstacles,
2) *Alignment*: attempt to match velocity (speed and direction) with neighbors,
3) *Cohesion*: attempt to stay close to neighbors.

Descriptions of both behaviors a flock and a shepherd are used for Boid's like scheme in this paper.

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2.1. Rules for flocking behavior

A flocking behavior is based on the following rules:

Rule 1: *Cohesion*: close to the nearest neighbor
Rule 2: *Separation*: avoid collisions with neighbors or obstacles
Rule 3: *Escape*: away from the shepherds
Rule 4: *Random action*: behave regardless of rules 1 and 2 stochastically

where rule 3 has the highest precedence and rule 4 is added to represent a realistic behavior of a flock. It is a noise element in the view of flock control. The flock behavior is generated based on these rules. A member of flock reacts only to the other members within a certain small neighborhood around itself. And they react to the shepherds within a certain area around itself. The former aria is called *personal zone* and the latter *safety zone* in this paper, respectively.

2.2. Rules for shepherding behavior

A shepherding is based on the following rules:

Rule 1: *Guidance*: guide a flock to an objective direction given by supervisor
Rule 2: *Flock making*: push back a wondering individuals to the flock
Rule 3: *Keeping*: keep a certain distance against flock's member to avoid disturbing order of a flock
Rule 4: *Cooperation*: avoid shepherds overlapping.

A shepherd reacts to the other shepherds with in a certain small area around itself, which is introduced to avoid them from overlapping each other. And they search the members of the flock within a certain area around itself. The former area is called *handling zone* and the latter is *watching zone* in this paper, respectively.

Movement of shepherd is determined based on an angle θ between the object's direction and the guidance direction as shown in Fig.1. Here, the object is a center of a flock for steering the flock and is a wondering individuals for pushing back it to the flock. The mechanism generates an effective guidance as shown in Fig.2

It is assumption that position information of individuals is detected by several sensors in the proposed method. Area around the individuals is divided into several small areas. One small area is covered by one sensor such as an ultra sonic sensor, IR sensor etc. Direction, distance, number of individuals and a center of a flock are estimated from the amount

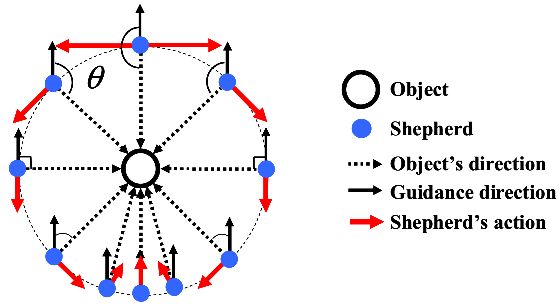

Fig.1 Shepherding behavior mechanism.

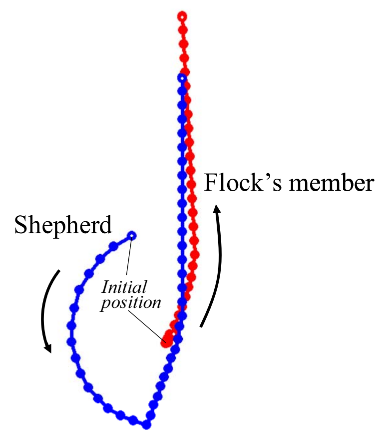

Fig.2 Shepherding behavior generated by the proposed mechanism.

of outputs of each sensor. It means that individuals behind other individuals can not be detected. We try to generate both behaviors (flock's action and shepherding) by using the mechanism based on such vague information.

3. Experiments

In this section, the performance of the proposed algorism is confirmed by computer simulations. In the simulations, the field size is 1200 x 900, size of individuals (includes shepherd) is 10. Ranges of personal zone, safety zone, watching zone and handling zone are 20, 80, 300 and 20, respectively. Maximum moved distances of the flock's member and the shepherd are 2 and 3 on a step, respectively. The maximum detection length for flock's members each other is 300 and the keeping distance between flock's members and shepherds is 75. A common unit is used for all parameters.

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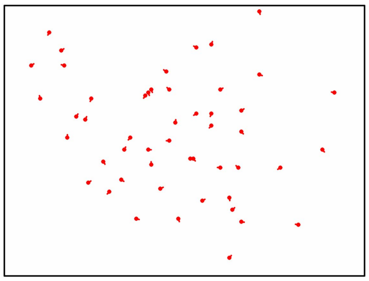
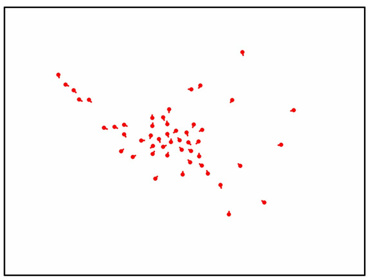
3.1. Simulations of the flock behavior

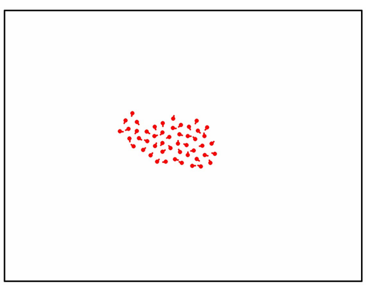
The process that the fifty sheep are gathered and become a crowd is shown in Fig. 3, where the initial positions of them are assigned at random. Fig.3 shows that flock is effectively constructed by the proposed method.



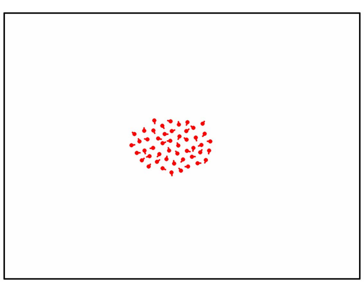
(a) Initial step



(b) 100 steps



(c) 500 steps



(d) 1000 steps

Fig.3 Flock's behavior generated by the proposed methods (50 members).

3.2. Simulation of flock guidance by single shepherd

Fig.4 shows flock guidance by single shepherd, where the number of flock's member is 10. The guidance direction is changed per 1500 steps (upper, right, lower right, left and stay). A good steering result is achieved. The shepherd is going to always push back the most far-off sheep from the flock to the center of the flock. Flock's member positioned on the both edge of the flock is apt to the far-off (wondering) individuals. Therefore the shepherd runs zigzag necessarily.

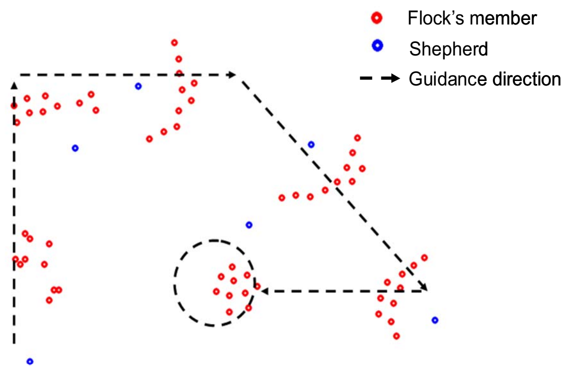


Fig.4 Flock guidance by single shepherd (flock's member is 10).

3.3. Results for the flock with a lot of members controlled by two shepherds

If the size of the flock becomes larger, only one shepherd can not control them. Fig.5 shows results of flock guidance by single shepherd and two shepherds. Here, the number of flock's member is 10, T1, T2 and T3 are guidance direction change spots. In this simulation, the direction is changed three times (first direction is upper right, next right, lower right, and stay). In Fig.5, the maker represents the center of the flock on a 100 steps and the line the trajectory, respectively. Fig.5 shows that the steering result employed by two shepherds is better performance than by single one.

The relations between the number of the flock's member and the moved distance and also the spread of the flock are shown in Fig.6. Here the results are the average of 500 iterations. As the flock's member increases, the moved distance decreases and also the flock spread over. On the other hand, the performance of flock guidance by two shepherds is better than by

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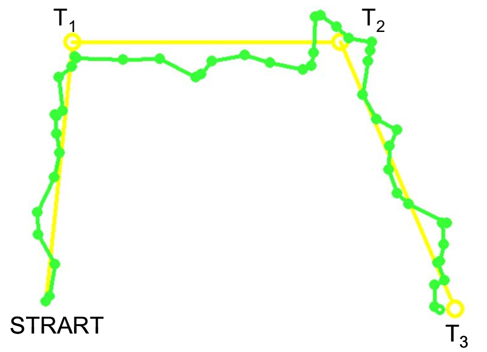
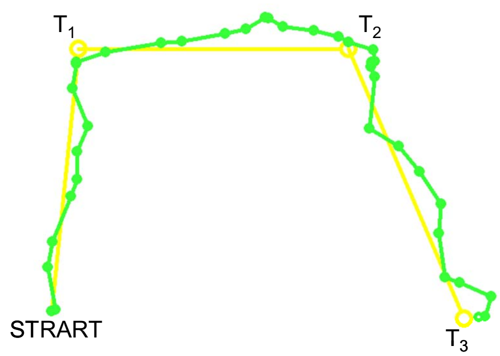
single shepherd regardless of the number of flock’s member. The limitation for guidable number of flock's member is about 25 for one shepherd and about 30 for two shepherds.



(a) Guided by single shepherd.



(b) Guided by two shepherds

Fig.5 Difference with trajectories of the flock’s center guided by (a) single shepherd and (b) two shepherds.

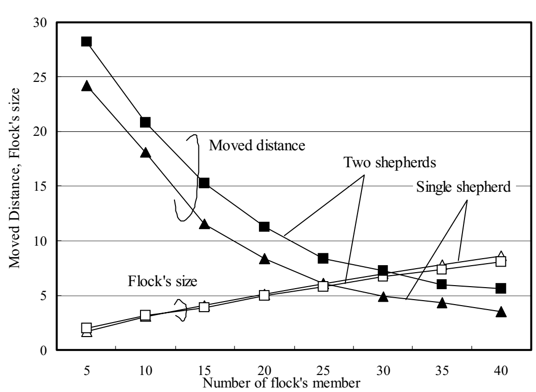


Fig. 6 Relations between the number of the flock's member and the moved distance and also the spread of the flock.

4. Conclusions

In this paper, an effective shepherding algorithm based on the simple rules was described. The performance of the proposed algorithm was confirmed for the shepherding simulations for a flock with about 25 members that are herded by single to two shepherds. The simulation results showed the proposed rules produced the effective cooperative action for shepherding autonomously. We are trying to implement the propose algorithm to small autonomous robots.

Acknowledgements

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