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Realization of Flock Behavior by Using Tau-margin

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Abstract: Recently autonomous robot that is designed based on biological mechanism has attracted much attention. In this paper we focus on mechanism of timing control which is studied in ecological psychology, and we apply it for controlling of multi mobile robot. Simulations have been conducted and various flock behaviors have been realized. In addition, we have confirmed that by using two leader robots, separation of flock is also possible. We can conclude that it is possible to realize flock behaviors by using the timing control without information of distance.

Keywords: multi mobile robot, timing control, ecological psychology

I. INTRODUCTION

Recently, autonomous robots which operate in unknown environment have attracted much attention. In particular, cooperative task by multi mobile robot is one of the most interesting applications, and control method for multi mobile robot has been proposed [1]-[3].

C.Reynols proposed an algorithm that is called "Boids". It can simulate cooperative behavior like flock of flying birds by simple three rules. These are "Steer to avoid crowding local flock mates", "Steer towards the average heading of local flock mates", and, "Steer to move toward the average position of local flock mates"[4]-[5].

As the algorithm is very simple, various approaches in which the algorithm is applied for controlling multi mobile robot have been studied. In these studies, the robots have to acquire information of other robots and the environment in order to cooperate. So, usually robot has some sensors that measures distance among the robots and obstacles [6]-[8]. However, lots of computational cost is required for recognizing the relation among the other robots, and it causes lack of agility of the robot.

On the other hand, animals can behave adaptively in the unknown environment without distance sensor. They do not know precise positional relation among the other animals. Instead of it, they use visual information for behaving adaptively. In ecological psychology, the mechanism that animals employ for perceiving the environment has been studied, and it is considered that animals employ information that means time to contact instead of information of distance. This time to contact is called "tau-margin", and it is confirmed that the "tau-margin" is used in various timing control [9].

In this paper, we apply the "tau-margin" of the ecological psychology to the robots, and conduct some simulations. And, we show that it is possible to realize flock behaviors without information of distance.

II. TAU-MARGIN

It is generally known that the perceptible distance by the stereoscopic vision is limited to a small scope within arm's reach. However, we can catch and avoid a ball coming toward ourself from somewhere. It is impossible to explain these things by using framework of the stereoscopic vision.

In ecological psychology, it is confirmed that timing control is possible without perceiving the information of distance. This is called "tau-margin" and explained by the following way. Fig.1 shows an image on the retina that an object produces.

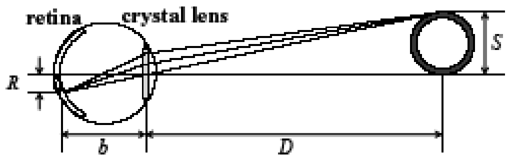

Fig. 1 Producing retinal image

The object size R which is produced on the retina is represented by the equation (1). Where b represents the distance from crystal lens to the retina, D represents the distance from the crystal lens to the object and S represents the real size of the object.

$$R = \frac{bS}{D} \tag{1}$$

The temporal differential of R is shown by equation (2).

$$\dot{R} = -\frac{bS}{D^2}\dot{D} \tag{2}$$

The time to contact which is called tau-margin is represented by equation (3).

$$\tau = -\frac{D}{\dot{D}} = \frac{R}{\dot{R}} \tag{3}$$

This equation means that the time to contact is directly perceived by using the object size R which is produced on the retina and its temporal variation $\dot{R}$ without information of distance to the object D and its relative velocity $\dot{D}$.

III.FLOCK BEHAVIOR USING TAU-MARGIN

1. Multi mobile robot

We consider multi mobile robots which operate in two-dimensional field. Motions of the robots are expressed by equation (4).

$$m\frac{d^2x(t)}{dt^2} - C\frac{dx(t)}{dt} = F \tag{4}$$

Where x is position vector in x-y coordinate, m is mass of a robot, C is viscosity resistance, and those values are positive constant. F is force of a robot, and it is decided by equation (5).

$$F = -K_p \cdot \frac{1}{\tau} \tag{5}$$

$$K_p : proportional \quad gain$$

2. Simulation

A. Simulation setting

The form of the robot is circular, and its diameter is 0.3m. The robot has single eye, and its field of vision is ±60 deg. The mass of a robot is 5.0kg, and the viscosity resistance C is 1.0 m^2/s. The proportional gain Kp is 50. The distance from the crystal lens to the retina is 0.02m.

Fig.2 shows the flowchart of the simulation.

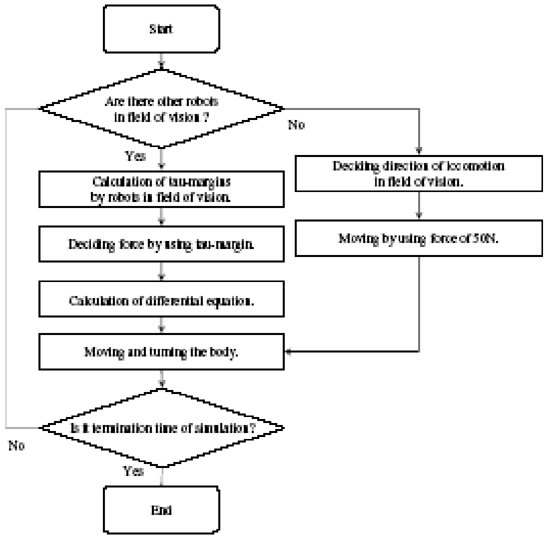

Fig. 2 Flowchart steps

If a robot perceives more than 2 robots in its field of vision, the robot uses minimum tau-margin of then, and decides driving force by using this tau-margin. Simulation time is 100 second, and its step size is 0.01 second. We employ Runge-Kutta method for calculating the differential equation.

A robot turns in the following ways. If a robot perceives the robot in its field of vision, it turns to the direction of other robot. And, if a robot perceives no robots in its field of vision, the direction is not changed.

We employ 6 robots, and a few of them are leader robots which move independently. And, default positions of follower robots are put within a circle that radius is 3 meters.

We set 4 different tasks written below.

a) Linear motion

One leader robot moves straightly from top to down.

b) Sine curve motion

One leader robot moves on sine curve from left to right.

c) Irregular motion

One leader robot moves straightly from left to right first. Next, it moves downward, and upstroke at an angle 45 deg. Finally, it moves right again.

d) Separate motion

Two leader robots move straightly from left to right first. Next, those robots move the opposite direction each other.

B. Simulation result

a) Linear motion

The follower robots follow the leader robot with keeping the initial formation.

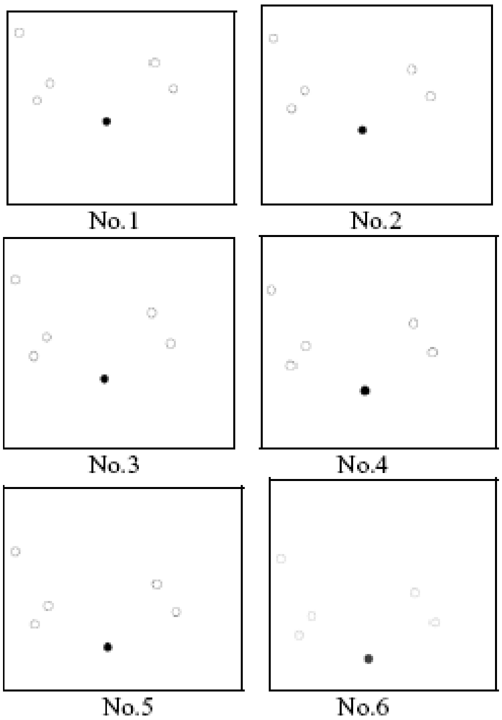

Fig. 3 The results of linear motion

Setting b) Sine curve motion

The follower robots keep the initial formation, and follow leader robot that moves on sine curve to horizontal direction.

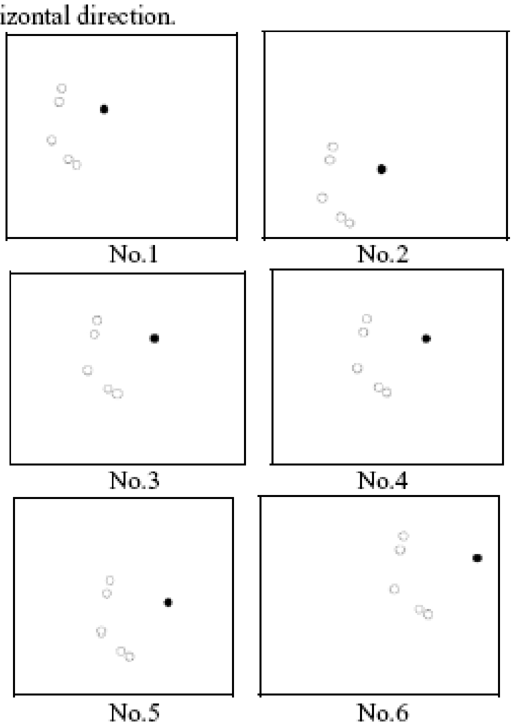

Fig. 4 The results of sine curve motion

Setting c) Irregular motion

The follower robots keep the initial formation, and follow leader robot that moves irregularly.

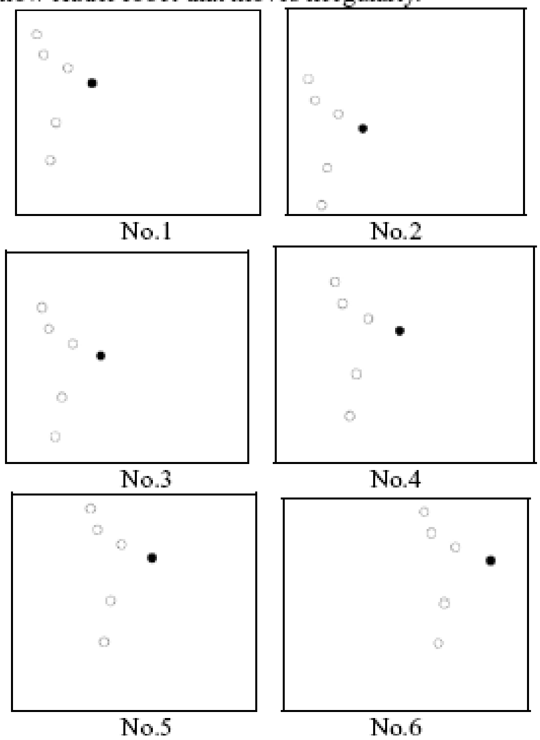

Fig. 5 The results of irregular motion

Setting d) Separate motion

When the leader robots separate to opposite direction, follower robots go to the direction of nearest leader robot. As a result, separation of flock is realized.

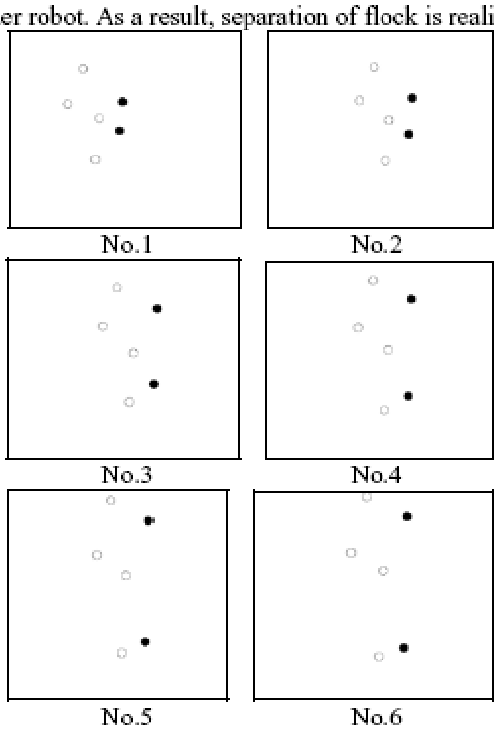

Fig. 6 The results of 2 leader robots

Fig. 7 to 10 show simulation results of $1/\tau$. Solid lines mean that temporal change in horizontal direction, and broken lines mean that temporal change in vertical direction.

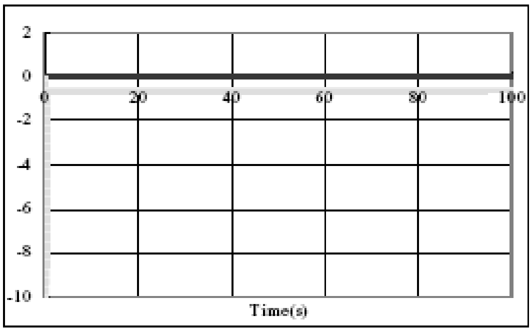

Fig. 7 The temporal change in $\frac{1}{\tau}$ of task a)

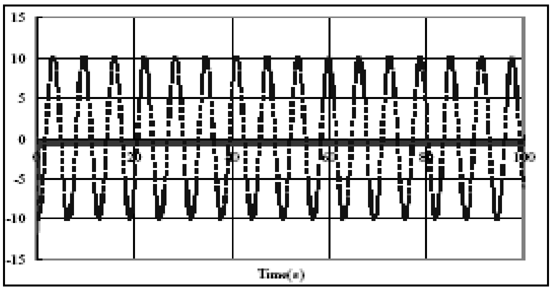

Fig. 8 The temporal change in $\frac{1}{\tau}$ of task b)

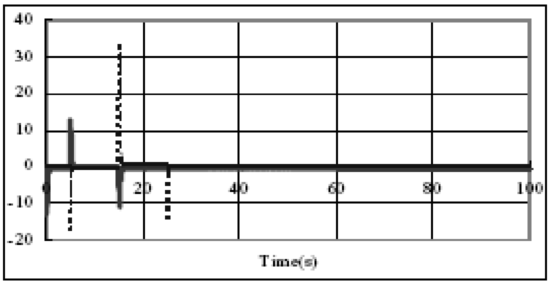

Fig. 9 The temporal change in $\frac{1}{\tau}$ of task c)

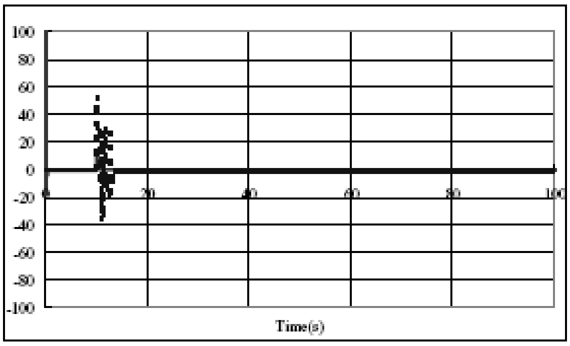

Fig. 10 The temporal change in $\frac{1}{\tau}$ of task d)

3. Discussion

In those simulation settings, it is impossible that robots perceive information of distance or velocity. However, follower robots move based on nearby robots. And, various flock behaviors have been realized based on leaders' behaviors.

We can confirm that leader follower task is realized by using tau-margin.

V. CONCLUSION

In this paper, we have applied the tau-margin of the ecological psychology to the multi mobile robot, and realized flock behavior.

We have conducted some simulations by using a few leader robots. In the result, flock behavior that follows up leader robots has realized. In addition, we have confirmed that by using two leader robots, separation of flock is also possible. We can conclude that it is possible to realize flock behaviors by using the "tau-margin" without information of distance.

REFERENCES

[1] Ito K (2005), Reinforcement Learning for Redundant Robot -Solution of state explosion problem in real world-. Workshop on Biomimetic Robotics and Biomimetic Control: 36-41

[2] Ito K (2006), Autonomous control of a snake-like robot utilizing passive mechanism. Proceedings of the 2006 IEEE International Conference on Robotics and Automation: 381-386

[3] Makino K (2004), Collective Behavior Control of Autonomous Mobile Robot Herds by Applying Simple Virtual Forces to Individual Robots (in Japanese). RSJ 22(8):31-42

[4] Reynolds C (1987), Flocks, herds, and schools: A distributed behavioral model. Computer Graphics 21(4):25-35

[5] Matunobe N (2003), Boid as self-organization criticality system (in Japanese). IPSJ SIG Technical Report 112(11):59-64

[6] Ota J (2002), Multi-agent Robot Systems (in Japanese). RSJ 20(5):487-490

[7] Arai Y (2001), Collision Avoidance in Multi-Robot Environment based on Local Communication (in Japanese). RSJ 19(1):45-58

[8] Yata T (1999), A Fast and Accurate Reflecting Points Measurable Sonar-ring System (in Japanese). RSJ 17(8):1173-1182

[9] Lee DN (1985), Visual timing of interceptive action. Brain mechanisms and spatial vision: 1-30