The Eighteenth International Symposium on Artificial Life and Robotics 2013 (AROB 18th '13),
Daejeon Convention Center, Daejeon, Korea, January 30-February 1, 2013

A method of sharing for common coordinate system by using relative position among the swarm

Makino Koji

Tokyo University of Technology, Japan
(Tel: 81-42-637-2111 ex.2823, Fax: 81-42-637-2112)

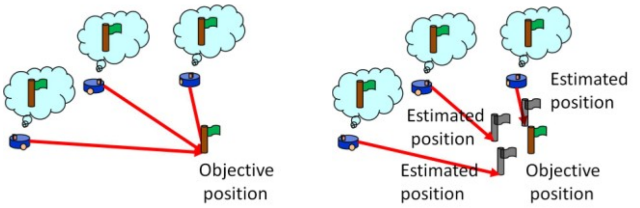
rmakino@stf.teu.ac.jp

Abstract: I have proposed a method that the many robots share the common coordinate system using dead-reckoning and observation to other robots without communication and without making the maps, like migration animals. To share the common coordinate system, both position and direction is necessary to be considered. I analyzed the effectiveness of the directional modification method, and confirmed it by simulations. In this paper, the modification of the position is focused on. First, the effectiveness of the method is confirmed by simulations. Secondly, the influence of the coefficient parameter of the positional modification is investigated, when the number of the robots and modification interval are changed. As a result, it is found out that the modification method of the position has optimal values.

Keywords: swarm, migration, common coordinate system

1 INTRODUCTION

A multi robot system that consists of many autonomous robots is drawing attention, because it has various advantages of fault tolerance, scalability and flexibility [1]. In many case, it is desirable that each robots recognizes own position and direction on the same coordinate system. For example, if all the robots recognize the flag position on the common coordinate system, they reach the position exactly (Fig. 1-a). On the other hand, assume that they can't recognize it on the common coordinate system (Fig. 1-b). However, it is difficult to share the common coordinate system. It is called as "localization problem". To solve the problem, GPS, SLAM[2][3], triangulation[4] and probabilistic methods[5][6] have been proposed. GPS is not available in the indoor, in the water, or outside the earth. The other method is necessary to communicate with other robots. Communication conflict occurs, if the large number of the robots exists.



a. on the common coordinate system   b. on different coordinate systems

Fig. 1. Recognition the objective position

I pay attention to the animal of natural world. Migrant animals (bird, animal, fish and insect) often move very long distance. And they can reach their destinations (the lake, the grassland, the river and the sea). They do not communicate position and direction with the others. However, they adjust own velocity to correspond with the others.

I have proposed a method that the many robots share the common coordinate system using dead-reckoning and observation to other robots without communication and without making the maps, like migration animals[7][8][9]. In this paper, the relation between the parameter of the positional modification and optimal value is reported.

2 ROBOT SYSTEM

In the proposed modification method, the robots must move to the same direction and position. In this paper, the control method of the robot swarm that has been proposed is applied [10]. The control method consists of many robots and a supervisor that broadcasts the same command to them (Fig. 1).

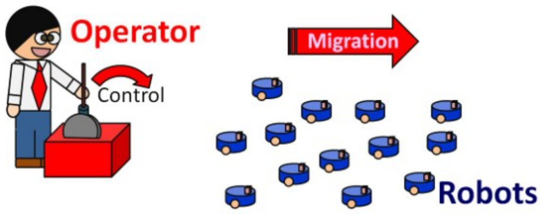


Fig. 2. The manipulation system

The robot has following ability:

- moving in 2-dimensional flat field
- localizing by dead-reckoning
- receiving the broadcast command from the supervisor
- measuring distance and relative velocity of other robots

where, the each robot does not communicate with each other. And, a general robot can be implemented with these abilities easily.

The robot receives three kinds of force. The force is similar to the force of the 'BOID' [11].

f_{ri} : attractive force to migrate

$$f_{ri} = K(p_r - p_i)$$

f_{ai} : attractive or repulsive force to gather

$$f_{ai} = \sum_{j \in J_{Ai}} \left(\frac{A_1(p_i - p_j)}{|p_i - p_j|^{m1}} - \frac{A_2(p_i - p_j)}{|p_i - p_j|^{m2}} \right)$$

And it decides the velocity by the sum of the forces

$$\dot{p}_i = f_{ri} + f_{ai}$$

In order to migrate, the reference position is changed according to

$$p_r = v_r t$$

The variable and constants are shown in Table 1.

Table 1. Definition of variables and constants

notation	description
$p_i = (x_i, y_i)^T$	absolute position of agent i
$p_r = (x_r, y_r)^T$	absolute position of reference position
$v_r = (v_{xr}, v_{yr})^T$	absolute velocity of reference position
n	number of agents
$K, A_1, A_2, B, m1, m2, m3$	constant value

Fig. 3 shows the simulation result that the robots move by using basic setting without localization error. The basic setting is described in section 4. All the robots migrate together.

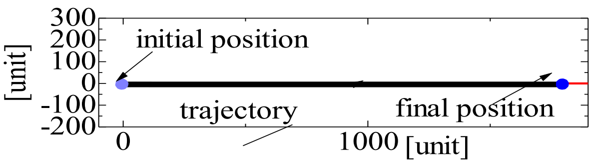


Fig. 3. Trajectories without localization error

3 MODIFICATION METHOD

3.1 Dead-Reckoning error

Dead-reckoning is very simple method to measure the own position and direction. However, the localization error occurs by dead-reckoning error. For example, the robot moves along dash trajectory for localization error in figure, though it tries to move to straight forward. Therefore, the robot estimates a different coordinate system to an initial coordinate system.

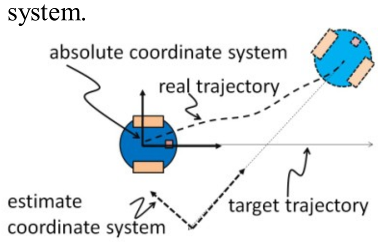


Fig. 4. localization error

Fig. 5 shows the trajectories of the robots. They move the different direction by the dead-reckoning error.

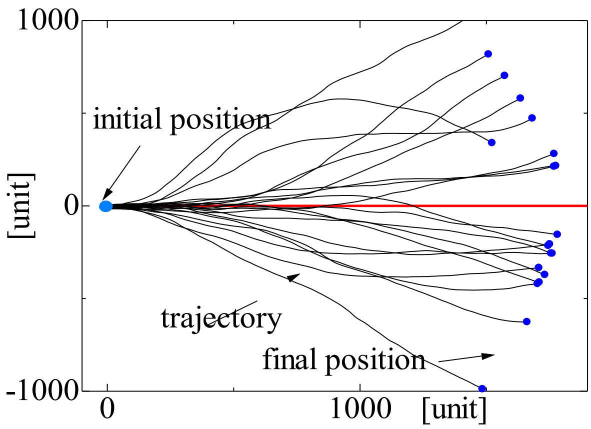


Fig. 5. Trajectories with localization error

3.2 Modification of the direction

The modification method of the direction is described. If all the robots recognize own position on the same coordinate system, they can move to same direction. Each robot modifies adjust own direction to fit direction of other robot, if they move to different direction by the error. The relationship between other and own velocity is illustrated in Fig. 6. The robot can observe relative velocity and can obtain own velocity. Therefore, it is able to calculate $\delta\theta_i$. And, it modifies own direction according to following equation:

$$\theta_i^+ = \theta_i^- + \omega_{dir}\delta\theta_i$$

where, superscript "+" and "–" mean after and before modification.

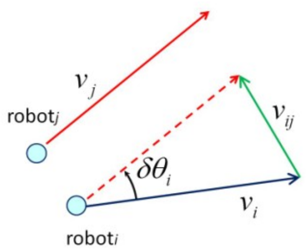


Fig. 6. Modification method of the position

Fig. 7 shows the trajectories with modification of the direction. All the robots migrate together in spite of the dead-reckoning error. This paper does not focus on the different between average trajectory and target trajectory, because it considers the sharing coordinate system.

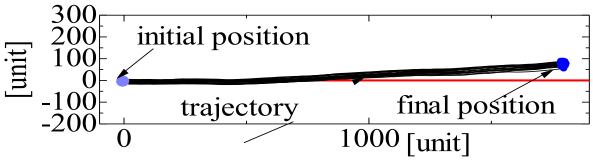


Fig. 7. Trajectories with directional modification without positional one

3.3 Modification of the position

The modification method of the position is described. The robots are not able to gather, if the each robot recognizes different reference position (Fig. 6). The own position is modified by f_{ai} and weight coefficient ω_{pos} as following equation:

$$p_i^+ = p_i^- + \omega_{pos} f_{ai}$$

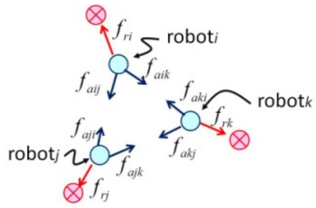


Fig. 8. Modification method of the position

The trajectories with modification of the direction and position are shown in Fig. 8. The trajectories are similar with ones in Fig. 7. The difference whether modification of the position is adopted or not is discussed in section 4.

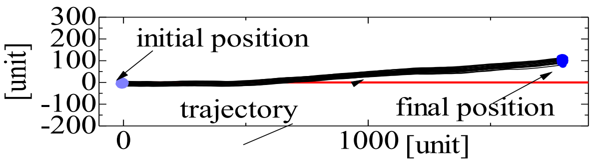


Fig. 9. Trajectories with directional and positional modification

4 SIMULATION

4.1. Setting

Basic setting is shown. The reference velocity is given as $(0.5, 0)^T$ [unit/step]. The dead-reckoning error is set to 2%, and the number of the robot is 20. The interval time between modifications is 20 [step]. The simulations are executed 10 times using different initial random value at the same parameter. The constant parameters K, A_1, A_2, m_1 and m_2 are 0.05, 1, 1, 1 and 2, respectively. The coefficient of the ω_{dir} is employed to 0.5. The optimal value of ω_{dir} is analyzed theoretically and confirmed by the simulation [9].

4.2. Effectiveness of modification of position

The time variant of the direction and position is illustrated in order to confirm the effectiveness of the modification method of the position.

First, standard deviation of the direction is shown in Fig. 10. The result using modification of the position (ω_{pos} = 0.2) is little worse. However, the value is not divergent.

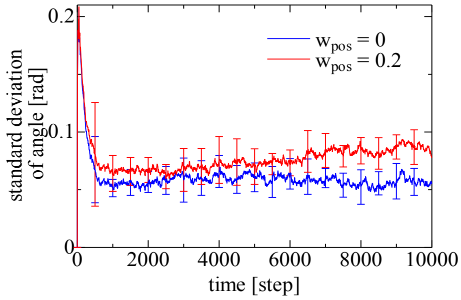


Fig. 10. Standard deviation of the direction

Secondly, Fig. 11 shows standard deviation of the position. The value without modification of the position (ω_{pos}=0) is divergent. On the other hand, the value with positional modification (ω_{pos} =0.2) is converge.

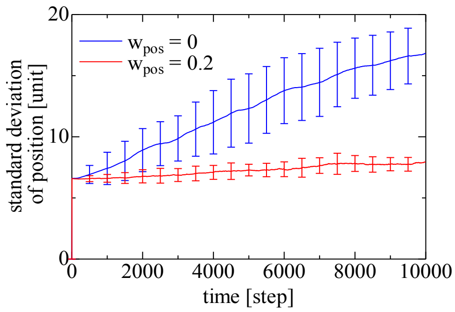
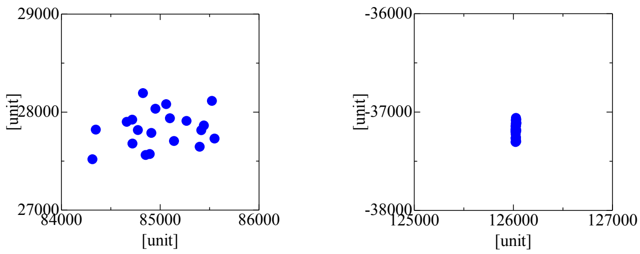


Fig. 11. Standard deviation of the position

Finally, Fig. 12 depicts final positions of the robots with and without modification, respectively. The position without modification is spread. However, the position is gathered using modification.



a. without positional modification

b. with positional modification

Fig. 12. Position of the 20 robots after long migration

The effectiveness of the modification method of the position is confirmed.

4.3. Influence of the parameters

In order to investigate the influence on the error of the position, the coefficient parameter of the modification of the position is changed from 0 to 1 step 0.01.

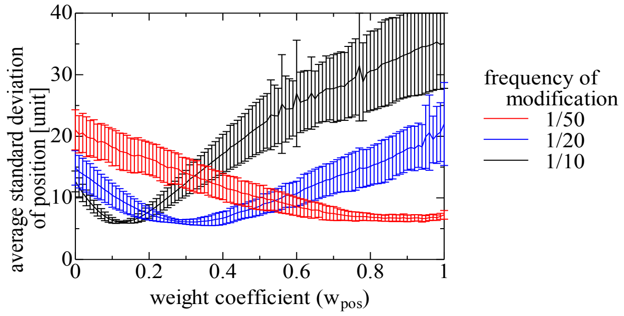


Fig. 13. Standard deviation of the direction changing ω_{pos}

Fig. 13 shows the results using three kinds of the interval times between modifications. Localization error increases, when interval time is long. Larger coefficient parameter is necessary in the case of large error. The robot might have to estimate scale of own error in order to use optimal value.

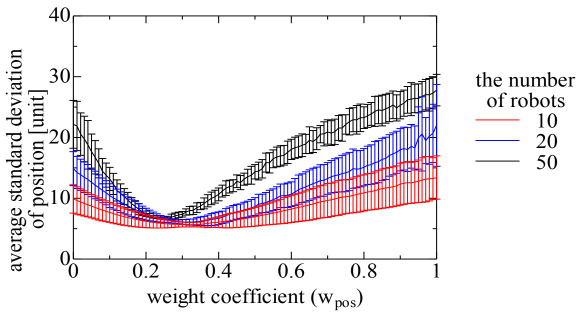


Fig. 14. Standard deviation of the direction various for ω_{pos}

The results using three kinds of the number of the robots (n = 10, 20, 50) is depicted in Fig. 15. The optimal value is the almost same, though the number of the robots is different.

5 CONCLUSION

This paper described the modification method of the direction and position in order to establish the common coordinate system. Both modification of position and direction are effectiveness to sharing direction and position, respectively. Especially, the influence of the coefficient parameter of the modification of the position on the performances is confirmed. I find that optimal parameter depend on the amount of the error, but does not depend on the number of robots.

In the future work, the effectiveness of the positional method is analyzed.

REFERENCES

[1] Y. U. CAO, et al. (1997), Cooperative Mobile Robotics: Antecedentsand Directions, Autonomous Robots, Vol. 4, No. 1, pp. 7-27.

[2] M.W.M.G. Dissanayake, S. Clark P.Newman, H.F. Durrant-Whyte, and M. Csorba (2001), A Solution to the simultaneous localization and map building problem, IEEE Transactions on Robotics and Automation, Vol. 17, No. 3, pp. 229-241.

[3] M. D. Marco, A. Garulli, A. Giannitrapani, and Antonio Vicino (2003), Simultaneous localization and map building for a team of cooperating robots: A set membership approach, IEEE Transactions on Robotics and Automation, Vol. 19, No. 2, pp, 238-249.

[4] KURAZUME, R., NAGATA, S and Hirose, S. (1994), Cooperative positioning with multiple robots, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Vol. 8, pp. 325-344.

[5] Fox, D. ,BURGARD, W, KRUPPA, H and THRUN, S. (2000), A probabilistic approach to collaborative multi-robot localization, Autonomous Robots, Vol. 2, pp. 1250-1257.

[6] IITSUKA, T, MAKINO, K, SHE, J, H and OHYAMA, Y (2010), Cooperative Localization of Autonomous Mobile Robots applied MCL method (in Japanese), 22th SICE Symposium on Decentralized Autonomous Systems, pp. 285-290.

[7] MAKINO, K. and MATSUO, Y. (2007), Method of Coordinate System Merging for Collective Control of Autonomous Mobile Robots (in Japanese), JRSJ, Vol. 25, No. 8, pp. 70-81.

[8] MAKINO, K. SHE, J. H. and OHYAMA, Y. (2010), Establishment of Common Coordinate System by Using Migration of Autonomous Robot Herd, SICE Annual Conference 2010, pp. 404-407.

[9] MAKINO, K. SHE, J. H. and OHYAMA, Y. (2011), Analysis of a Method of Sharing for Common Coordinate System by Migration, SICE Annual Conference 2011, pp. 2484-2487.

[10] MAKINO, K. and MATSUO, Y. (2004), Collective Behavior Control of Autonomous Mobile Robot Herds by Applying Simple Virtual Forces to Individual Robots (in Japanese), JRSJ, Vol. 22, No. 8, pp. 79-90.

[11] Craig W. Reynolds (1987), Flocks, herds and schools: A distributed behavioral model, SIGGRAPH '87 Proceedings of the 14th annual conference on Computer graphics and interactive techniques, pp. 25-34.