Shepherding algorithm of Multi-mobile robot system

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Abstract—**This paper introduces a simple algorithm and design of shepherding multi-robot system. The article intends to show possibility of using multi-robot system for shepherding in Mongolia. Shepherding is an activity to guide or control a flocking behavior by one or more agents called as shepherds man. In general, a complex strategy is necessary for treating to a flock which has a lot of members. In the paper, two types of shepherding multi-robots are used to show their capability to herd the sheep. Furthermore, we designed a simple structure for shepherding multi-robot system and demonstrated an algorithm. Two types of multi-robot systems like corner mobile robots and sideline mobile robots are used for shepherding. Mobile robots are connected to each other and are controlled by the given algorithm. Mobile robots should be high mobility and be able to go through uneven road.**

Keywords-shepherding; multi shepherd; flocking; multi-mobile robot; robot control

I. INTRODUCTION

In this project, capability and possibility of using multi-robot system for shepherding process in Mongolia are presented. Mongolia is country of animal husbandry. In 2009, total number of livestock in Mongolia became 43657.1 thousand. Among them, the sheep is 19125.2 thousand, goat is 19470.5 thousand [6].

From above mentioned evaluation, we can see that shepherding system of flock and its control systems are very important for Mongolia. Currently, Mongolians do not use robot technique for shepherding behavior. We can estimate average size of Mongolian sheep and goat as 64-96 centimeter in height, 64-72 centimeter in length, round size of abdomen is 80-95 centimeter, and approximate weight is 32-70 kilogram [7]. Therefore we can understand that our robot system will control above sized object. Modeling and simulating of flock behavior has been studied by many researchers in a variety fields such as robotics, control, biology etc [2, 3, 4, 11]. Generally, complex theory is necessary to treat complex and unpredictable behaviors. A boid model, proposed by C.Raynolds, had a break because of certain problems. 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 researches [1, 12].

II. 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 [1]. The model describes realistically a complex behavior of a flock by only three simple rules as below:

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.

If we use Boid schema, the flocking behavior and shepherding behavior will be described by the following rules.

A. 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 existed to represent a realistic behavior of a flock. 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.

B. A shepherding is based on the following rules

Rule 1 – Guidance: guide a flock to an objective direction given by operator.

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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 within 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. Movement of shepherd is determined based on an angle between the object's direction and the guidance direction.

We can simulate the behavior by the above algorithm and model but shepherding behavior is uncomfortable because condition of Mongolia is pastoral cattle breeding, antipodal climate and much more flock. Approximately in condition of Mongolia, number of flock and livestock is 300-1000. Therefore we can use following multi-robot system and their cooperation. This algorithm is very simple structure. Most same systems of shepherding apply operation using one or two shepherd.

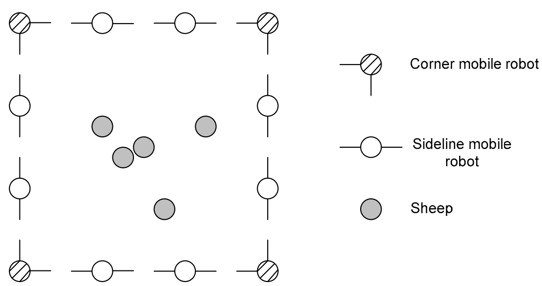

Figure 1a. The location of shepherding multi-robots system

However, our proposed system is particularity using by multi-robot system and cooperation of multi-robot. Using robot in this system is two type. One of type is corner mobile robot; other one type is sideline mobile robot. We can see type of robots in Fig. 1a, Fig. 1b. This solution is efficient if flock is much more.

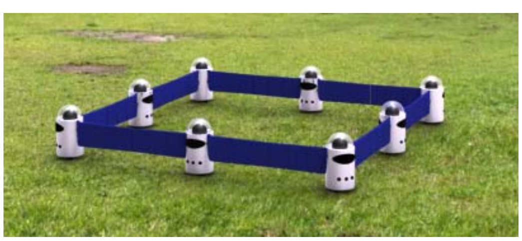

Figure1b. The cooperation multi-functional robots

C. Implementation:

The group of multi-robots executes three types of operation and algorithm. There:

- To herd flock to grassland
- To pasture flock
- To collect flock back to home

The first and third operations are the same, yet target points are different. Functional feature of the second algorithm stands to not allow the flock to go outside of the target zone. When the robots collect the flock and back to home, robot zone gets diminished in size. The following figure shows the algorithm.

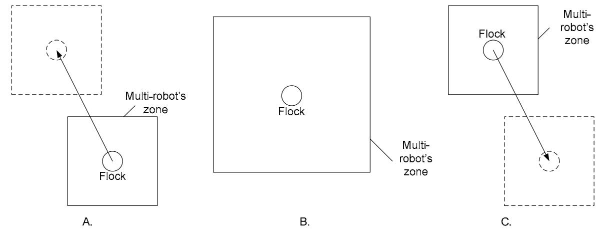

Figure 2. Execution algorithm of a group of multi-robot system
A. to herd flock to grassland,
B. to pasture flock,
C. to collect flock and back to home

Quantity of robots will be selected depending on space (square meter) of zone and robot model.

$$n = \frac{\sqrt{S}}{2r_2+r_1} \qquad (1)$$

There: S – the square of zone multi-robots' execution

r_1 – the inside diameter of mobile robot

r_2 – the length of from inside radius to outside radius of mobile robot

There, square of robot zone depends on possible space of grassland for each sheep:

$$S = n * S_1 \qquad (2)$$

There: n – the number of flock

S_1 – the possible pasture square of a sheep

Designs of the corner and sideline mobile robots are shown in the Fig. 3 and Fig. 4.

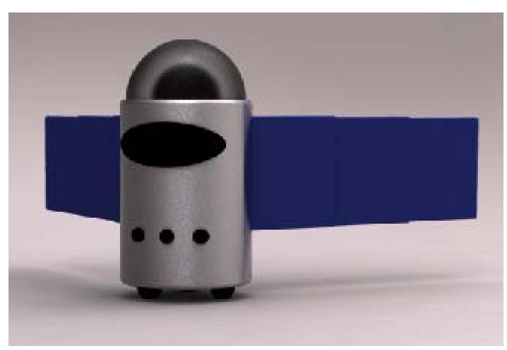

Figure 3a. The corner mobile robot

Figure 3b. The corner mobile robot

Figure 4. The sideline mobile robot

Using solar panel and batteries for power supply of multi robots is very efficient solution [5]. Every robot is controlled by operator and exchanges information to each other using wireless communication. We can use Zigbee and electronic compass to estimate distance between the multi-robots [8]. In this case, we can describe distance between the multi-robots by using RSSI (Received signal strength indicator) based Zigbee. RSSI is mainly intended to measure the signal power loss when the electromagnetic wave travels in space and compare it with the signal power decay obtained from theory or experiments in order to transform the signal power loss to the distance that signal travels. In free space, the signal power received on the spot with a distance of d to the transmitter can be expressed as follows [9, 10].

$$RSSID(d) = \begin{cases} pt - 40.2 - 20xlgd & x < 8 \\ pt - 58.5 - 33xlgd & x \geq 8 \end{cases} \quad (3)$$

There: pt is transmitting power and RSSI(d) is the received signal strength on the spot with the distance of d to the transmitter. From the formula, the received power decay logarithmically with distance. So we can measure the signal strength and compute the approximate distance.

Technical structure of a robot is shown in the Fig. 5.

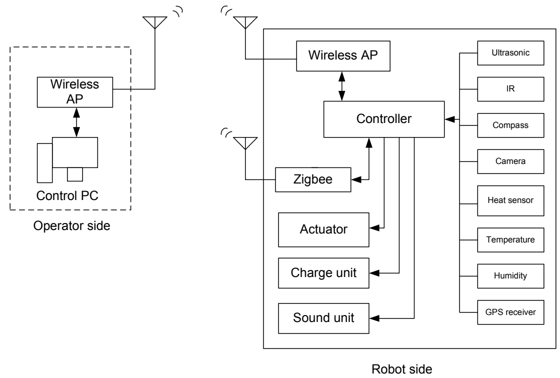

Figure 5. The system structure of each robot

D. *The execution algorithm of a group of shepherding multi-robots:*

The execution algorithm has three section as above mentioned. Besides, multi-robots turn into charging mode after collecting flock backing home in normal regime. While the robots are executing algorithm, they can be charged from solar energy, not only turning into charging mode. Its algorithm is shown in the Fig. 6 below.

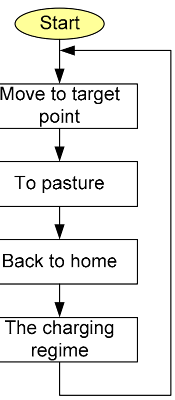

Figure 6. The main algorithm

Here, we describe each sub-algorithm. First, algorithm is "move to target point" algorithm shown in the Fig. 7.

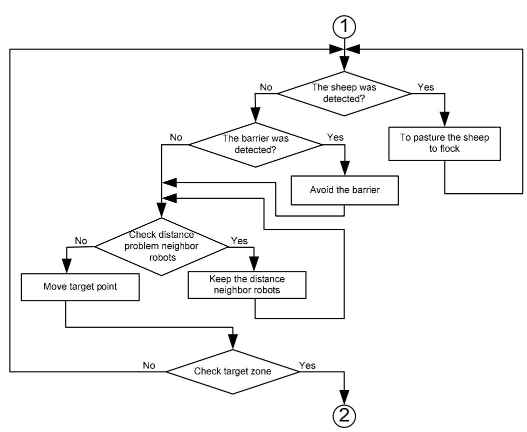

Figure 7. "Move to target point" algorithm

During this sub-algorithm, multi-robots will move to the target zone. Meanwhile, they will herd sheep occurred on the way to target zone and if any obstacle occurs on the way they will get over it keeping distance between robots. After reaching at target zone, the robots will continue activity by the next algorithm shown in the Fig. 8. The main operation in this duration is to pasture the flock. As pasture space is different than space of herding, robots will expand the space and set pasture zone newly.

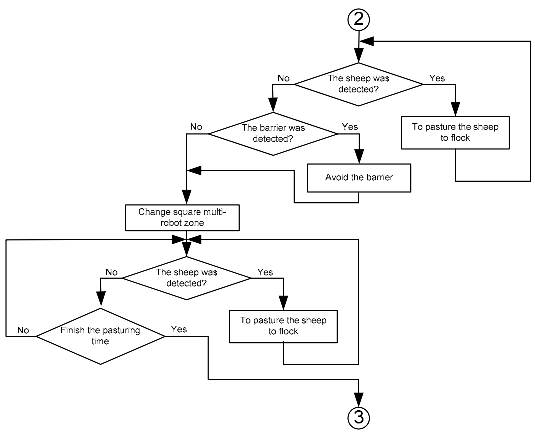

Figure 8. “To pasture” algorithm

Pasture process will continue until the time given by operator ends. The algorithm to back home is shown in the Fig. 9. This algorithm is the same with the algorithm “Move to target point”. Its target position is different only. After coming back, the regime of the multi-robot system should be turned into charging mode.

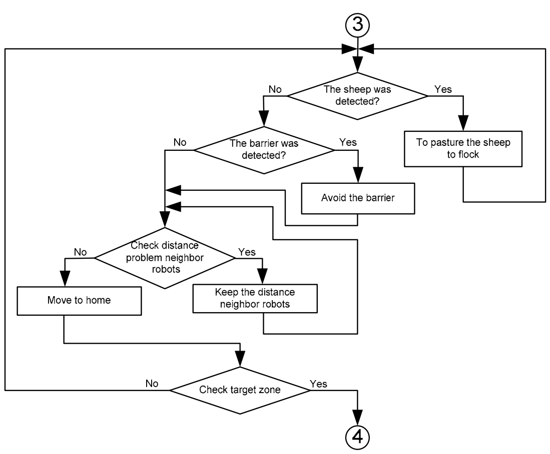

Figure 9. “Back to home” algorithm

III. CONCLUSIONS

As far as you know Mongolia has a large number of livestock and pastoral cattle breeding in vast areas. However, shepherding algorithms are not presented before in this field. Therefore, appropriate algorithm and technical solution are required for shepherding. This paper presents control algorithm and multi-robot system.

Demonstrating of simple execution algorithm, group of multi-robots are used this research.

In addition, there, solar batteries are possible to charge multi-robot system.

In the future, there is required to study more and to make on research works in this field.

REFERENCES

[1] Tsutomu Miki, Tetsuya Nakamura, “An Effective Simple Shepherding Algorithm Suitable for Implementation to a Multi-mobile Robot System”, International Conference on Innovative Computing, Information and Control, 2006.

[2] Jyh-Ming Lien, Samuel Rodriguez, Jean-Phillipe Malric, Nancy M.Amato, “Shepherding Behaviors with Multiple Shepherds”, International Conference on Robotics and Automation Barcelona, Spain, April 2005, pp.3402-3407, 2005.

[3] Jyh-Ming Lien, Samuel Rodriguez, Jean-Phillipe Malric, Nancy M.Amato, “Shepherding Behaviors”, International conference on Robotics and Automation New Orleans. LA-April 2004, pp.4159-4164, 2004.

[4] Mitchell A.Potter, Lisa A.Meeden, Alan C.Schultz, “Heterogeneity in the Coevolved Behaviors of Mobile Robots: Emergence of Specialists”, The Seventeenth International Conference on Artificial Intelligence, August 4-10, 2001.

[5] T.Zupa, K.Zidek, O.Liska, J.Zivcak, “Global Navigation and Collision Protection System of Mobile Robots for Interoperation Transport”, pp.199-201, 2008.

[6] http://economics.gogo.mn/news/64282

[7] http://www.estandard.mn/filebase/files/1556-83.pdf

[8] Yong Yang, Guiyun Xu, Xinyu Wu, Huiwei, Yangsheng Xu, “Parent-child robot system for rescue missions”, International conference on Robotics and Biomimetics, pp.14271432, 2009.

[9] Zhang Jieying, Sun Maohang and Wang Xia, “Dynamic distance estimation method based on RSSI and LQI”, Electronic Measurement Technology, February 2007, pp.142-145.

[10] IEEEStd. 802.15.4-2003 Website, Available:http://www.ieee802.org/15/pub/TG4.html.

[11] Richard Vaughan, Neil Sumpter, Jane Henderson, Andy Frost, Stephen Cameron, “Robot control of animal flocks”, ISIC/CIRA/ISAS Joint Conference Gaithersburg, MD, September 14-17, 1998, pp.277-282.

[12] Craig W.Reynolds, “Flock, herds and schools: A distributed behavioral model”, Computer Graphics. 21(4):25-34, Jul 1987.