Potential field method applied on the navigation of multiple mobile robots with limited ultrasonic sensing

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Abstract: Multi-robot manipulation can accomplish complex task with simple robot systems comparing with singular mobile robot. In spite of systemic simplicity, multi-robot cause subsidiary problem, group driving. Each mobile robots have to consider not only target and obstacles but also other member robots. Previous researches attempt to solve it by using communication and formation method. As this paper studies to solve the problem in the simplest way, it is proposed the formatted navigation method using simple microrobots equipped with ultrasonic sensor without network communications. The navigation is based on potential field algorithm, and virtual hill concept is applied for the formation. Before the experimental test, this paper shows the simulation test to evaluate proposed method.

Keywords: multiple mobile robots, formation, virtual hill, navigation, platoon, potential field

I. INTRODUCTION

As working as human performance, robot requests several sensors and actuators. However, increasing sensors and actuators occur system complexity problems. Especially as mobile robot basically has to pursue safe and right driving as well as another requested task, the robot can meet serious problem at the several addition of sensors and actuators for the special purpose. For the problem, many researches approach the problem with cooperative manipulation by multi robots [1]. However, in the multi mobile robot system, corporative driving and manipulation occurs new problem. Each mobile robot has to consider not only target and obstacles but also other member robots. To solve it, many researches adopt network communication and machine vision system [2][3]. But, these solutions are still contraposed against system simplicity.

This study researches the solution laying emphasis on the system simplification. The system simplification is acquired by only using economic ultrasonic sensors for the environmental recognition without any other sensors and network devices. For a start, this paper considers only multi mobile robot navigation before researching the manipulation. This challenge can contribute for reducing operating load for driving and in same time increasing program space for other task.

In this paper, whole robots' driving is proposed based on platoon formatted navigation. The formation is made up by virtual hill method which helps mobile robots make a set-upped distance with other ones. In the proposed method, all mobile robots follow potential ingredient decent direction not only avoiding obstacle but also keeping distance with other member robots.

The previous research done by P. Song, and V. Kumar showed that potential field method is adoptable in multi mobile robot navigation [4]. The study was based on vision system. But, this paper wishes to contribute to make a multi robot navigation method affordable to very simplified system.

In this paper, potential field method is briefly explained and virtual hill method is introduced. The adoptable simple multi mobile robots are modeled for simulation test. And simulation test evaluates the proposed method before experimental test.

II. Potential Field Method

1. Goal Navigation

A variety of effective attraction and repulsion potential fields are summarized in [5], [6]. Let

$r_{ij} = \| r_i - r_j \|$ be the Euclidean distance between robot and the object or the goal, a simple quadratic attractive potential function can be expressed as

$$V_{io}^{a} = 1/2 k_{io} r_{io}^{2} \quad (1)$$

r_i and r_o are the position vectors of the robot and the object, respectively.

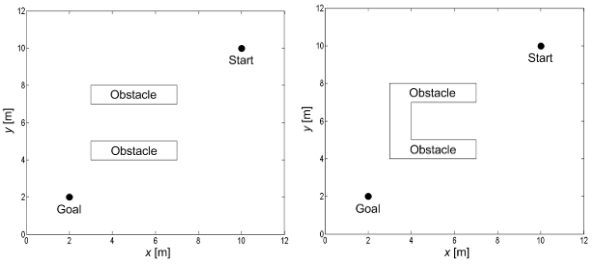
An expression of the repulsive potential is

$$V_{ij}^{r} = k_{ij} / r_{ij} \quad (2)$$

where $r_{ij} = \| r_i - r_j \|$ is the Euclidean distance between robots i and j. In each control mode, the force vector generated by potential fields and an appropriately designed dissipative function provide the driving force to the robots.

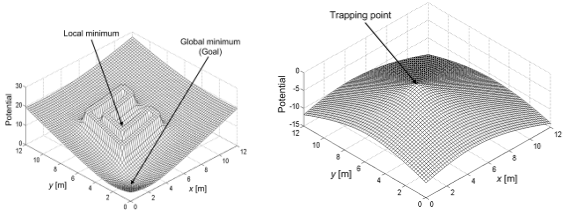
2. Artificial Virtual Hill

The artificial virtual hill was proposed in previous research to avoid local minimum [7]. In unknown environments, the robot initially does not have any information about the environment, and it has a limited sensing range to detect obstacles. The environment in Fig. 1(a) does not contain a local minimum, so robots may successfully reach the goal using the general potential field approach. In the environment of Fig. 1(b), however, robots may be trapped in a local minimum as Fig.2(a). In the study, the virtual hill in global potential was proposed as Fig. 2(b). And then final global field become as Fig. 3.



(a) Open aisle (b) Closed aisle

Fig. 1. Two types of obstacles with aisle shapes



(a) The potential field (b) virtual hill

Fig. 2. The potential field and virtual hill

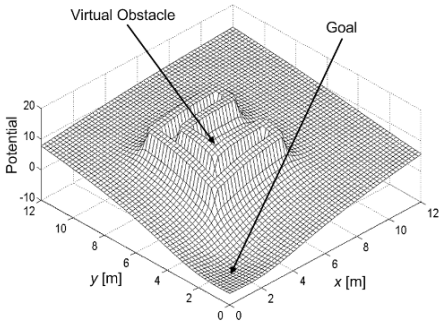


Fig. 3. Global potential with a virtual obstacle

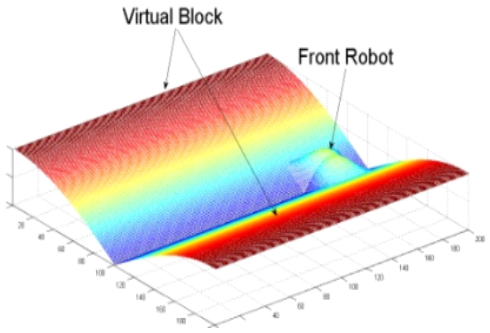


Fig. 4. Virtual hill for one line formation

3. One Line Formation

In this paper, the virtual field is applied to make a formation of multi robots as Fig. 4.Fig 4 is simple one line formation potential field. In the figure, high hill is shown. This hill can keep robot follow front robot. But between robots, there occurs a few repulsive potential energy to keep a few distance between robots. The repulsive hill to make line formation is paralleled with the line made between goal and leader robot. If there are three mobile robots in the field, only one or two of them can recognize the goal point. Although a few member know and pursue the goal, if other members unknowing the goal just drive to make a formation, the all of them can reach the goal by cooperative navigation in the end.

Except all robots do not recognize the goal, there are three cases of states. The one is that only one robot knows the goal. The second case is that two robot recognize the goal and the other doesn't. The third one is that all member find the goal same time.

A. Only one robot recognize goal

The first case is beginning state. If robot find only goal without other member, the robot will approaches the goal only. Remaining robots follows the first moving members.

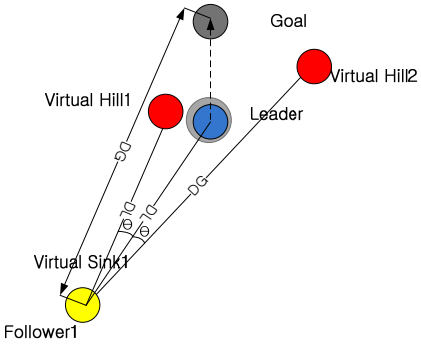


Fig. 5. The Potential field of the first followers

B. Two robot recognize goal

If there are goal and one other robot in the sensor view, the robot compares the distance to goal and other robot. From the result of distance, the shortest distance robot becomes the leader which just pursues the goal. And remaining robot becomes follower.

If the robot becomes follower, then it makes 2 virtual hills as shown in Fig. 5. The first hill is located on the line to goal with the distance to the leader. And the second hill is set on the deposited point to leader with same angle between goal and leader. The distance toward second hill is the same one to goal.

C. Remaining follower

If there are two more robots and goal in the view of robot, the robots distinguish the leader and the front follower by comparing relative distance with goals. If two more robots is shown and goal is not founded in the view of robot, the robot searches the first moving robot who will become the leader. Then by comparing the distance to the leader, the robot decides its order.

The second follower robot set the virtual sink which is temporary goal and two virtual hills as shown in Fig. 6. When the robot decides the lower priority order, the virtual sink is set at the nearest member to leader robot.

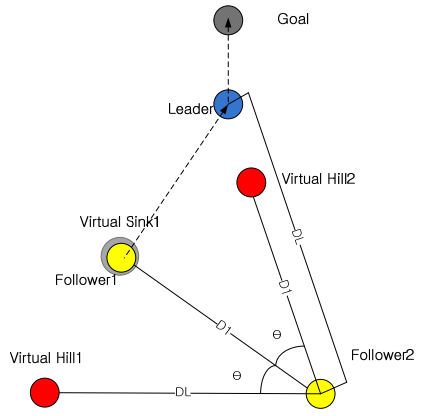


Fig. 6. The Potential field of the second followers

Two virtual hills are set as Fig 6. One is set on the line to leader. The other is set on the opposite site to virtual sink with same angular between the sink and leader. The distance is same as the one to sink. Thus, after making line formation, the relative potential field becomes as Fig. 4.

III. Simulation Test

1. Robot Modeling

The whole study will evaluate the proposed technique using experimental test. This paper does it using simulation test before experimental test. Thus, this chapter describes the simulation model based on experimental system. Fig. 7 shows the concept designs of the robot figure on the stocks. The robot is centralized 2 wheels robot equipped rotatable ultrasonic sensor scanner, 2 IR photodiodes and IR ramp array. The purpose of IR usage is recognition of other robot. But the communication is not implied. The IR sensors are also attached on the ultrasonic sensor scanner to get the direction of the member robots. Fig. 8(a) shows the prototype of ultrasonic sensors scanner. 2 directional sensors is designed to be rotated 90 degree to get the environment distance within 180 degree. Fig. 8(b) is the experimental test result. Table 1 is the designed specification of robot and environment.

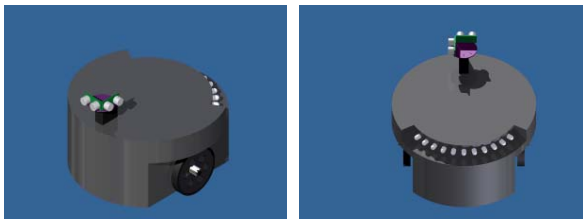
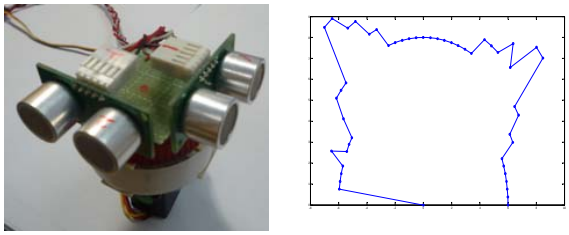


Fig. 7. Concept designs of the experimental robot



(a) Ultrasonic Scanner (b)Experimental test result

Fig. 8. Concept designs of the experimental robot

Table 1. Specification of Multi mobile robot system

Sort	Specification
Robot Size	200(D)150(H)
Field Size	4,000(W) 4,000(L)
The range of Ultrasonic sensor	3,000mm
The degree of Ultrasonic sensor	180 degree
Maximum Velocity of	20mm/sec
Number of Robot in flied	3

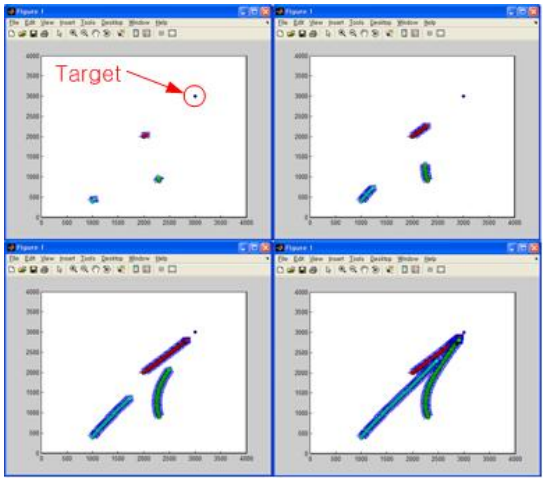


Fig. 9. Simulation test result

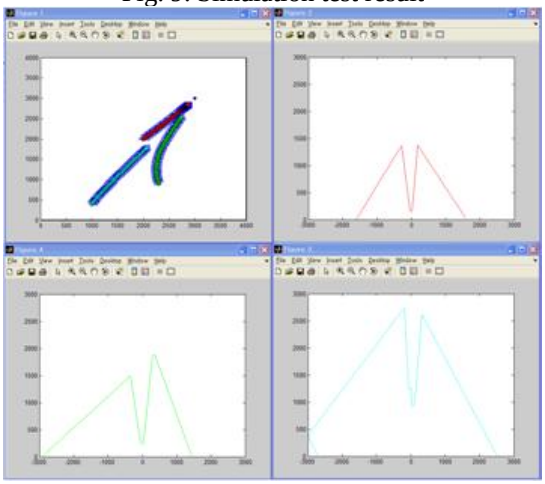


Fig. 10. Sensors monitoring in Simulation test

2. Simulation Test

The proposed formation method using potential virtual hill is evaluated by simulation test. The robots were located in the 4 by 4 meter simulation field arbitrarily. Fig. 9 is the simulation test result showing the progress of formation and navigation. From the repetitious test and various case of initial setting, the result reveals that the proposed algorithm make a line formation and goal arrival in simulation test. Fig. 10 shows the ultrasonic sensor recognition of each robot during simulation test. From the result, it is known that the robot can approach in the tail of front robot or target goal and find out only front robot and goal in the sensored range result.The whole study will evaluate the proposed technique using experimental test. This paper does it using simulation test before experimental test.

VI. CONCLUSION

This paper studies the multi mobile robot formation and navigation method in the simplest system by only using ultrasonic sensors for environmental recognition. The potential field method is adopted to drive mobile robot. To achieve corporative navigation, this paper proposed line formation method using virtual hilled potential field navigation. The proposed method was evaluated simulation test. In the future, experimental test has to be executed and compared with simulation test

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