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Speech Based Formation Control of multiple Mobile Robots

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Abstract: The article presents multiple pattern formation control of the multi-robot system using A* searching algorithm, and avoids the collision points of motion paths. We use speech recognition algorithm to control the variety pattern formations exchange, and use mobile robots to present the movement scenario on the grid based motion platform. We have been developed some pattern formations according to game applications, such as long snake pattern formation, phalanx pattern formation, crane wing pattern formation, sword pattern formation, cone pattern formation and so on. The mobile robot contains a controller module, three IR sensor modules, a voice module, a wireless RF module, a compass module, and two DC servomotors. The mobile robot can acquires the detection signals from reflect IR sensor modules and compass module, and decides the cross points of the aisle, and receives the command from the supervised compute, and transmits the status of environment to the supervised computer via wireless RF interface. We develop the user interface of the multi-robot system to program motion paths for variety pattern formation exchange on the minimum displacement. Users can use speech to control the multiple mobile robots to executed pattern formation exchange on step by step or continuously. In the experimental results, mobile robots can receive the pattern formation command from the supervised computer, and change the pattern formation on the motion platform, and avoid other mobile robots.

Keywords: pattern formation exchange control, multi-robot system, A* searching algorithm, phalanx pattern formation, DC servomotors, wireless RF interface

I. INTRODUCTION

With the robotic technologies development with each passing day, mobile robot systems have been widely employed in many applications. Recently, more and more researchers are interest in the intelligent mobile robots which can help people in our daily life, such as entertaining robots, museum docent robots, educational robots, medical robots, service robots, office robots, security robots, home robots, and so on. In the future, we believe that intelligent robot will play an important role in our daily life. To design a big sized mobile robot to be equipped with many functions to become complex and huge, and the development period is too long. Thus, recently small-sized mobile robot systems have been investigated for a specific task, and program the optimal motion path on the dynamic environment [1].

There is a growing in multi-robot cooperation research in recent year. Compare to single mobile robot, cooperation multiple mobile robots can lead to faster task completion, higher quality solution, as well as increase robustness owing its ability adjust to robot failure [2]. Grabowski and Navapro-serment [3] suggested multiple mobile robots in which each mobile platform had a specific sensor for some purpose and therefore the system's task can be distributed to each mobile platform during surveillance. The feature of this system is that each mobile robot had a common motion platform, but had different sensors. Some papers consider the problem of the multiple robot system working together. The multiple mobile robot system has more advantages than one single robot system [4]. The multiple mobile robots have the potential to finish some tasks faster than a single robot using searching algorithm or ant colony algorithm [5].

Liu proposed a motion planning approach to coordinating multiple mobile robots moving along specified paths for minimizing formation errors [6]. The mobile robots are required to maintain the formation relationship, and are subject to the restrictions of velocity and acceleration bounds and collision avoidance [7]. Javier described work on multi-robot pattern formation. Arbitrary target patterns are represented with an optimal final formation [8]. The pattern formation is developed in ancient Chinese history. Sun Tzu and Zhuge Liang that are the symbol of resourcefulness and wisdom in Chinese Folklore proposed many pattern formations. The paper develops the multiple mobile robots to implement some pattern information.

II. SYSTEM ARCHITECTURE

The system architecture of the team robot system is shown in Fig 1. The system contains a supervised computer, a microphone, a motion platform, some wireless RF modules and five mobile robots. The supervised computer programs five pattern formations to be shown in Fig. 2. We name the pattern formations to be long snake pattern formation, wild goose pattern formation, sword pattern formation, cone pattern formation and crane wing pattern formation. Users can select each pattern formation using Chinese speech on the supervised computer. The supervised computer can programs the motion paths of the multiple mobile robots using minimum displacement method, and transfer change the pattern formation to the assigned pattern formation. The mobile robots move on the motion platform, and avoid collision with other robots. The supervised computer can transmits the command of the final locations to each mobile robot. The mobile robots can move to the final locations autonomous according to the programmed motion paths.

There are more merits in the mobile robots to use team robot cooperation capabilities to such a large fleet of robots. In general, the control structure of the large fleet mobile robots is classified centralized control and decentralized control. A centralized control requires robust and permanent communication capabilities between all mobile robots and the supervised system. A decentralized control only requires local communication between robots and the supervised system. Each mobile robot of the multiple robots' system will communicates with the other robots [9]. The paper uses the centralized control in the pattern formation arrangement. That is to say, the multiple mobile robots only communicate with the supervised computer via wireless RF interface. The mobile robot has been developed in my laboratory.

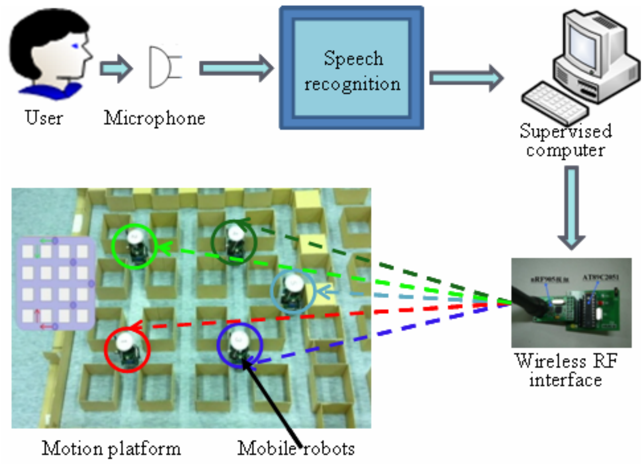
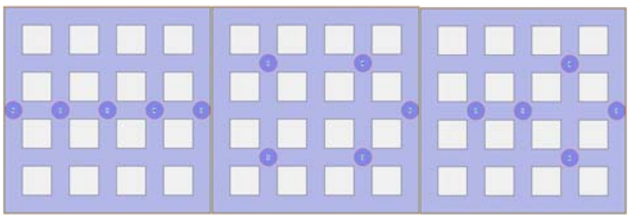
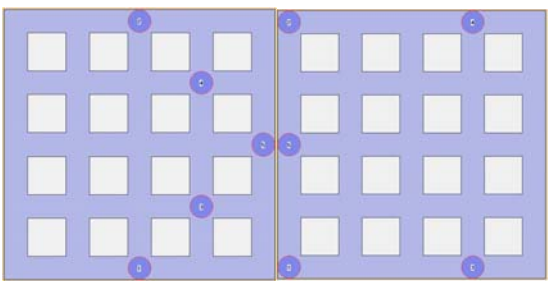


Fig. 1. The system architecture



(a) Long snake pattern (b) Wild goose pattern (c) Sword pattern



(d) Cone pattern (e) Crane wing

Fig. 2. The pattern formation model of multiple mobile robots

The core of the wireless RF module is microprocessor (AT89C2051), and communicates with the controller of the mobile robot or the supervised computer via series interface (RS232). The communication protocol of the system is 10 bytes. There are start byte (1 byte), data byte (8 bytes) and check byte (1 byte). The data bytes contain ID code (1 byte), robot code (1 byte) position and orientation data bytes. The ID code decides the transmitting direction between of the supervised computer and the multiple mobile robots.

III. Pattern Analysis

We program the shortest motion path of the pattern formation exchange using A* searching algorithm for each mobile robot, and locate the start position and final position of each mobile robot. The start position is the start point of the pattern formation, and the final position is the final point of the assigned pattern formation. The programmed motion paths have collision condition at the cross point of the programmed motion paths. The short displacement based mobile robot must stay at the original position to wait the long displacement based mobile robot moving through the point. Then the mobile robot moves through the point.

A^* searching algorithm solves the shortest path problem of multiple nodes travel system. The formula of A^* searching algorithm is following

$$f(n) = g(n) + h(n) \qquad (1)$$

The core part of an intelligent searching algorithm is the definition of a proper heuristic function $f(n)$. $g(n)$ is the exact cost at sample time n from start point to the target point. $h(n)$ is the minimum cost. In this study, n is reschedules as n' to generate an approximate minimum cost schedule for the next point. The equation (1) can be rewritten as follows:

$$f(n) = g(n) + h(n') \qquad (2)$$

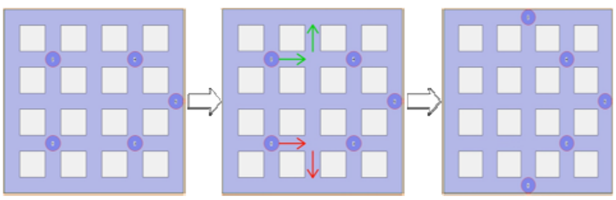


Fig 3. Wild goose pattern formation to cone formation

Now we make some examples to explain how to control pattern formation exchange using A* searching algorithm. The first example, the wild goose pattern formation transfers to the cone pattern formation to be shown in Fig. 3. The supervised computer programs the minimum robots to move on the assigned pattern formation, and can computes the shortest displacement of the selected robots moving to the assigned positions. We can see the only two mobile robots moving to the new assigned positions according to the cone pattern formation. Then the three mobile robots stay at the original positions. The total movement displacement is minimum value. The experimental results are shown in Fig. 3(b) and (c).

In the other example, is shown in Fig. 4. The long snake pattern formation transfers to the sword pattern formation. We program the motion paths of five mobile robots to exchange the formation, and use A* searching algorithm to program motion paths of moving robots, and uses the minimum moving robots on the pattern formation. Finally, we can see the only two mobile robots moving to the assigned positions. The others are stay at the original positions.

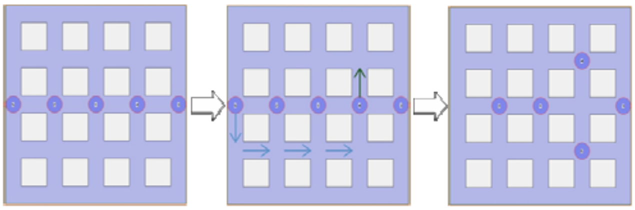


Fig 4. Long snake pattern formation to sword pattern formation

The structure of speech recognition is shown in Fig. 5. In speech signal processing, preemphasis, namely, the compression of the signal dynamic range by flattening the spectral tilt, preemphasis can also be accomplished after A/D conversion through differential calculation or through application of the first-order digital filter.

$$H(z) = 1 - a \times z^{-1} \tag{3}$$

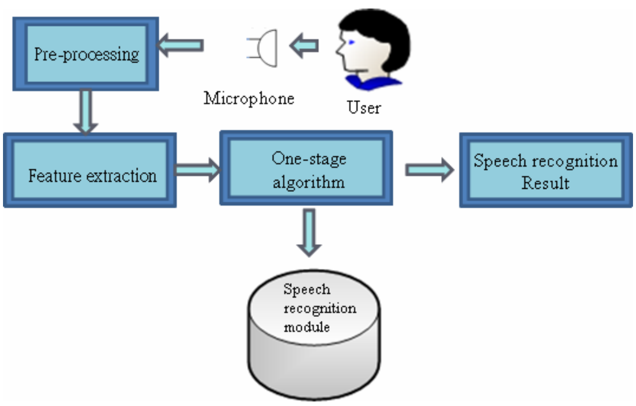


Fig 5. The structure of speech recognition

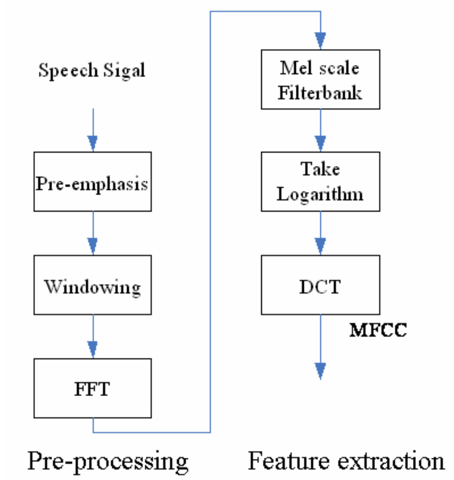


Fig. 6. The flow-chart of feature extraction

In the speech recognition, we want to extract the N-sample interval from the speech wave for calculating the autocorrelation function and spectrum. The speech wave must multiply by an appropriate time window. Thus several compromise window functions have been proposed. Among these, we use the Hamming window $W(n)$ as following [10]:

$$W(n,a) = (1-a) - a \times \cos(2\pi n/(N-1)), 0 \le n \le N-1 \tag{4}$$

We take $a = 0.46$ in the paper. We want to analyze the speech wave, and transfer the speech signals in the time domain to the frequency domain. The energy spectrum presents the phenomenon of variety speech signals. Then we can use Mel frequency to analyze the speech signals. The relation of Mel frequency and general frequency as following:

$$mel(f) = 2595 * \log 10(1 + f/700) \tag{5}$$

or

$$mel(f) = 1125 * \ln(1 + f/700) \tag{6}$$

Then we can find 12-level Mel-scale coefficients using discrete cosine transform (DFT) as following:

$$C_m = \sum_{k=1}^{M} E_k \cos[\left(k - \frac{1}{2}\right)\frac{\pi}{M}], m = 1,\ldots\ldots, L \tag{7}$$

Then we program the flow chart of feature extraction for speech recognition for variety pattern formation of the team robots to be shown in Fig. 6.

IV. EXPERIMENTAL RESULTS

We implement the pattern formation exchange control using five mobile robots, and presents the movement scenarios of the pattern formation exchanges on the grid based motion platform (One grid is 30 cm on the platform). The first formation exchange is the wild goose pattern formation transform to the cone pattern formation. The formation exchange only moves two robots, and uses A* searching algorithm and minimum movement displacement to program the motion paths that are plotted in Fig. 7, and transfers the wild goose pattern formation to the cone pattern formation.

In the experiment scenario, we use five mobile robots to arrange the wild goose pattern formation on the motion platform. The supervised computer transmits the cone pattern formation command to the five mobile robots via wireless RF interface, and assigns the new positions for five mobile robots. The experimental scenario of the first step is shown in Fig. 7(a). The two mobile robots move forward 30 cm (one grid) according to the programmed motion paths. Then one turns right 90^0 moving forward 30cm. The other turns left 90^0 moving for ward 30cm. The two mobile robots stop, and face the right side to be the same direction as the original direction for all mobile robots. The experimental scenarios are shown in Fig. 7(b) and (c). Finally, the five mobile robots leave the original location, and stay at the new positions to arrange cone pattern formation on the platform.

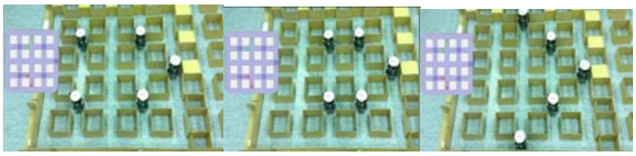


Fig. 7. The scenario of wild pattern to cone pattern

Next we implement the pattern formation exchange control using five mobile robots, and present the movement scenarios from the cone pattern formation to the wild goose pattern formation. The formation exchange only moves two robots, too. In the experiment scenario, the supervised computer transmits the wild goose pattern formation command to the five mobile robots via wireless RF interface, and transmits the new positions to the assigned two mobile robots. The experimental scenario of the first step is shown in Fig. 8(a). The two mobile robots turn 180^0 to move forward 30 cm (one grid). Then one turns right 90^0 moving forward 30cm. The other turns left 90^0 moving for ward 30cm. The two mobile robots stop, and face the right side. The experimental scenario of the first step is shown in Fig. 8(b) and (c).

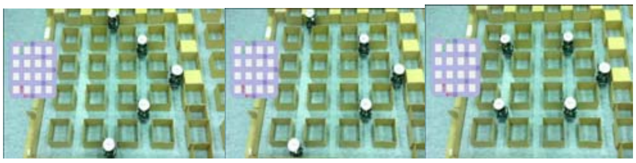


Fig. 8. The scenario of cone pattern to wild pattern

Finally we implement the pattern formation exchange control using five mobile robots, and present the movement scenarios from the long snake pattern formation to the sword pattern formation. The formation exchange only moves two robots, too. In the experiment scenario, the supervised computer transmits the sword pattern formation command to the five mobile robots via wireless RF interface, and transmits the new positions to the assigned two mobile robots. The experimental scenario of the first step is shown in Fig. 9(a). One mobile robot turn left 90^0 to move forward 30 cm (one grid), and turns right 90^0 to face right side. The tail of the snake (robot) turns right 90^0 moving for ward 30cm. Then the robot turns left 90^0 to move forward 90cm (3grids). The five mobile robots stop, and face the right side. The experimental scenario of the first step is shown in Fig. 9(b) and (c).

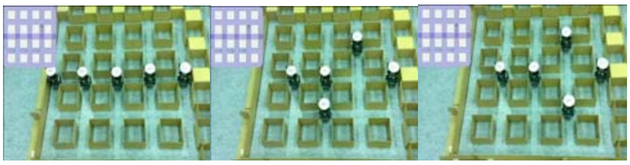


Fig. 9. The scenario of long snake pattern to sword pattern

V. CONCLUSION

We have developed five pattern formations' exchange control of the team robot system. The five pattern formations have long snake pattern formation, wild goose pattern formation, sword pattern formation, cone pattern formation and crane wing pattern formation. The formation control system contains a supervised computer, some wireless RF modules, a motion platform and five mobile robots. Users can use Chinese speech to control the multiple mobile robots to exchange pattern formation. The supervised computer can controls five mobile robots, and receives the status of the multiple mobile robots via wireless RF interface. The paper has been presented multiple pattern formation exchange control using five mobile robots. The experimental scenario of the four mobile robots moves on the motion platform, and obeys the programmed motion paths using A* searching algorithm. The five mobile robots can avoid the other mobile robots in the pattern formation control. In the future, we want to develop more complexity pattern formation using more and more mobile robots for war game, and develop the pattern formation programming according to the war laws of Sun Tzu or Zhuge Liang.

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