Research on gait planning of Hexapod wheel legged robot based on STM32 single chip microcomputer

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Abstract. In this paper, the rectangular wheel legged hexapod robot is used as the experimental robot, the STM32 single-chip microcomputer is used as the main control core, the steering control board is used as the auxiliary board, the upper computer programming is used to write the action group of the hexapod robot, the command is sent to the single-chip microcomputer through the PS2 handle, the single-chip microcomputer controls the steering board to achieve the corresponding action group, and the Arduino control board is used to change the environment through the sensor in the later stage. The control of action group can be realized by the detection. In addition, in order to solve the gait planning problem of hexapod robot and realize the optimal learning of robot's free gait on specific terrain, based on the discretization of the robot's single foot distance, integrating the time rhythm principle of CPG model and the space rule constraint mechanism of reflection model, a discrete gait model of Hexapod robot is constructed. Ant colony algorithm is used to study the gait path planning of the robot. MATLAB and C language technology are used to realize the simulation of the gait planning of the hexapod robot.

1. Introduction
With the continuous development and progress of society, although the scope of human involvement is increasing, there are still some special occasions that may endanger our lives in human society and nature, such as deep mountains, disaster mines[1-3], rescue and rescue, and places that human beings currently have no way to reach. These places have one common topographical feature: ruggedness and irregularity. It is not difficult to see that the wheeled robot has absolute advantages in speed and flexibility on the relatively flat road, but on the uneven road, the energy consumption of the wheeled robot is more obvious and the flexibility is greatly reduced. Compared with the crawler robot[4-6], it has more advantages in uneven ground, but it has defects in mobility and balance. Compared with the wheeled and crawler mobile robots, the walking robot on the rough road has superior performance[7-8].

The research of hexapod robot in China is relatively late compared with foreign countries, but with the development of science and technology, the development of hexapod robot technology is more and more perfect. In this paper, five conclusions are put forward for the motion planning of a six legged ant robot designed by Beijing University of technology. Huazhong University of science and technology has designed and manufactured "4 + 2" hexapod robot, which can better adapt to complex environment and work more efficiently. But at present, these hexapod robots can't really do bionics, and the influence of gait path plays an important role.
Therefore, based on the advantages of hexapod robot and wheeled mobile robot, this paper designs a wheel leg hybrid robot. Through the continuous transformation of wheel and foot, the hybrid robot can not only realize the fast driving on the flat road, but also realize the smooth passing on the rough ground. In addition, ant colony algorithm is used to study the path planning of the robot, and the gait planning simulation of the hexapod robot is carried out with STM32 single chip microcomputer.

2. The overall structure design of Hexapod Robot

2.1. Selection of mechanical structure of Hexapod Robot
There are three main ways of combination of wheel and leg: one is the combination of wheel and leg; the other is the independence of wheel and leg; the last is the combination of wheel and leg. There are many mechanical structures of Hexapod robots, most of which are mainly circular and rectangular[9]. In this project, the rectangular mechanical structure is adopted, as shown in Figure 1. The wheels and legs of the robot are relatively independent and installed on the body of the robot independently. When the legs fold in a certain direction, the wheels will contact with the ground, and then the robot can do wheeled motion; when the joints are extended and standing, the wheels will be separated from the ground, and then the robot can do leg walking. Compared with the circular mechanical structure, the parallelism of the six legs in the rectangular mechanical structure just satisfies the parallel movement of two groups of wheels when the robot changes from foot to wheel.

![Figure 1. three dimensional mechanical structure of Hexapod Robot.](image)

2.2. Selection of control panel
The control board is the core of the whole hexapod robot. There are many kinds of control boards, such as raspberry pie, 32 single chip microcomputer, 51 single chip microcomputer, Arduino control board and so on. Considering the influence of the whole project on intelligent control and convenient operation of hexapod robot, board area and power consumption, and the powerful PWM output efficiency, fast running speed, large memory, powerful engineering programming environment and a large number of IO ports of 32 single chip microcomputer, 32 single chip microcomputer is selected as the main control board[10]. The project adopts STM32series single chip microcomputer of STM company, 10 series single chip microcomputer has high performance, low cost, low power consumption, 144 pins, which provides more io for the project. The core adopts arm cortex™-m3 micro controller, 1 µs dual 12 bit ADC, 4 megabit / s UART, 18 megabit / s SPI, 18 MHz I / O turnover speed.

3. Wheel leg conversion of Hexapod Robot

3.1. The shape of wheel leg transformation
Due to the multi joint characteristics of the hexapod robot and the rectangular mechanical structure we use, we imitate the shape of the multi wheel steering of the six wheel armored vehicle, so that the hexapod robot will take on the shape of the six wheel motor vehicle after deformation. At the same time, we use the multi joint mobility of the hexapod robot to realize the multi steering of the six wheels, making the robot more flexible and turn at the same time It is more convenient to turn to two wheels or speed than before. The requirement of motor speed is not so high, and the operation is relatively simple.
3.2. The control of the deformation of six legged robot's foot wheel by STM32 single chip microcomputer

In this paper, we use 32 single chip microcomputer to control the steering gear control board, and we use PS2 handle to control the overall manual. The command is sent to 32 single chip microcomputer through PS2 handle. After receiving the command, the single chip microcomputer sends the corresponding command to the steering gear control board through serial port. After receiving the command, the steering gear control board makes the corresponding action group or action to complete the deformation task. The flow chart is shown in Figure 3:

![Flow chart](image)

**Figure 3.** Single chip command flow chart.

4. The implementation of ant colony algorithm in path planning

4.1. Basic principle of ant colony algorithm

Ant colony algorithm is a kind of swarm intelligence algorithm [7-8] which is inspired by the idea of observing the real ant colony foraging. After a lot of practice by researchers, it has been proved that when ants are searching for food, they can leave a kind of substance called pheromone on their way, so that later ants can not only perceive the intensity of pheromone, but also get the direction of guidance. If the distance between ants' nest and food is relatively short, the number of ants carrying food back and forth will increase. After a long period of time, there will be a positive feedback phenomenon. The phenomenon is that when a certain path is shorter, the number of ants passing through the path will increase, and the intensity of pheromone will be higher, so the probability of ants choosing this path will increase. The higher the rate. Through this positive feedback phenomenon, the optimal path will be obtained.

4.2. The preparation of ant colony algorithm

4.2.1. Environment modelling. In order to better study the path planning of robot, it is necessary to build a digital model of the random environment around the robot, and transform the environment information into matrix storage. The data 1 in the matrix indicates that there is an obstacle in front that cannot pass, and 0 indicates that there is no obstacle in front that can pass. Finally, it is expressed in the form of grid map.

4.2.2. Grid map. In this paper, the hexapod robot and obstacles are reduced in proportion, and the scale size of the hexapod robot is taken as the size of a grid, so the hexapod robot can be regarded as a particle. If the location of the map is an obstacle, the color of the grid is black, indicating that the obstacle cannot pass. If the grid is white, it means that there is no barrier. The establishment of coordinate system in this paper is closely related to grid map. Take the lower left corner of the grid map as the origin, the horizontal direction of the grid map is x axis, and the vertical direction is y axis.
5. Ant colony algorithm for shortest path planning

5.1. Basic steps of ant colony algorithm

The basic idea of ant colony algorithm comes from the principle of the shortest path for ants in nature to find food. According to the observation of insect scientists, it is found that although the vision of ants in nature is not developed, they can find the shortest path from food source to nest without any hint, and search the new best path adaptively after the environment changes.

The specific steps of the algorithm are as follows:

- **Step1**: Initialization of relevant parameters, including ant colony size, pheromone factor, heuristic function factor, pheromone volatility factor, pheromone constant, maximum number of iterations, etc., as well as reading data into the program, and preprocessing: for example, transforming the coordinate information of the city into the distance matrix between cities.

- **Step 2**: Put ants at different starting points randomly, and calculate the next visiting city for each ant until there are ants visiting all cities.

- **Step 3**: Calculate the path length $L_K$ of each ant, record the optimal solution of the current iteration times, and update the pheromone concentration on the path.

- **Step 4**: Determine whether the maximum number of iterations is reached, if not, return to step 2; yes, end the program.

- **Step 5**: Output the results, and output the relevant indexes in the process of optimization, such as running time, convergence iterations, etc.

Using ant colony algorithm to realize the shortest path planning of robot in the complex environment with obstacles is as follows:

Firstly, the working environment of hexapod robot is established by grid method. The environment information is represented by a matrix of only 1 and 0. Where 0 means that it can pass, 1 means that it is an obstacle and cannot pass.

The initialization map is represented by an example. The initialization grid map code is as follows:

```plaintext
map = [0 0 0 0 0 0 0 0 0 0 0; 0 0 0 0 0 0 0 0 0 0 0; 0 0 0 0 0 0 0 0 0 0 0; 0 0 0 0 0 0 0 0 0 0 0; 0 0 0 0 0 0 0 0 0 0 0;]
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Next, we need to initialize an pheromone matrix, and some parameters, such as start position, final position and other parameters.

Then, after determining the initial position, we need to find the next accessible position. This is what we do. According to the pheromone concentration of each node, the probability of going to each node is calculated. Here, the wheel algorithm is selected to select the starting point of the next step. The formula of wheel disk method is as follows:

$$P_{ij}^k = \frac{[\tau_{ij}(t)]^\alpha [\eta_{ij}]^\beta}{\sum_{k \in \{N - tabu_k\}} [\tau_{ij}(t)]^\alpha [\eta_{ij}]^\beta}, \quad j \in \{N - tabu_k\}$$

Table 1 shows the parameter interpretation of wheel algorithm formula

| $\tau_{ij}(t)$ | The concentration of pheromones on the arc (i, j) in the graph |
| $\eta_{ij}(t)$ | Heuristic information associated with arc (i, j) |
5.2. Ant colony algorithm path planning experiment

In order to verify the effectiveness of the algorithm, a large number of simulation experiments are done in this paper, respectively considering the work space with arbitrary obstacles and different complexity. The working environment of the robot is modeled as a grid of \((20 \times 20)\). The scale of traditional ant colony algorithm is set to 30, and the maximum number of iterations of the algorithm is set to 300. Figure 4 below shows the number of iterations and the length of the shortest path of the robot.

![Figure 4. Variation of iteration times and shortest path length](image)

6. Conclusion

In this project, the main control board of 32 single chip microcomputer, the wheel foot conversion controlled by PS2 handle and the corresponding action group controlled by sensor with arduino as auxiliary board are realized. Based on the flexible characteristics of the leg joints of the multi legged robot and the characteristics of being able to better adapt to the surrounding environment, this paper analyzes the gait movement of the six legged robot and the shortest path planning of the simulation robot under the ant colony algorithm in the complex environment with obstacles. The experiment proves that the ant colony algorithm can evaluate the convergence of the gait planning of the six legged robot in the complex scene and give the shortest path. How to further improve the stability and obstacles while quickly finding the shortest path is the next research goal.

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