Design and Research of Distributed Control System for Humanoid Robot Based on Automation Technology

Hao Guo*, Wei Jiang, Congwang Bao

Department of mechanical manufacturing, School of Mining & Civil engineering, Liupanshui Normal University, Liupanshui City, Guizhou Province, China 553004

*Corresponding Author email: 543446354@qq.com

Abstract

Humanoid robots have incomparable advantages compared with other types of robots. They are easy to integrate into human daily life and work environment and help human to complete specific tasks. The decision-making and action of each individual in a group are independent, but there is a wide range of altruistic cooperative behavior within the group. As a complex multi-degree-of-freedom system, robots need to effectively use their multi-sensor information to sense the external environment and their own state changes, and adjust their motion actuators. In different task requirements, the shape of distributed control and the severity of maintaining distribution are different, so the requirements for environment are also different. Compared with centralized control, distributed control system has more flexibility and stronger robustness. Based on automation technology, the distributed control system of humanoid robot is analyzed and designed according to the characteristics of humanoid robot system with many degrees of freedom and high requirements for real-time and reliability.

Keywords

Humanoid robots; Distributed control; Automation.

1. Introduction

Humanoid robots have incomparable advantages over other types of robots. They are easy to integrate into human's daily life and working environment and assist human to complete specific tasks [1]. Intelligent humanoid robot is a kind of robot system that can sense the environment and its own state through sensors and realize the autonomous movement towards the target in the environment with obstacles, thus completing certain operation functions. People finish tasks that a single robot cannot finish through cooperation of multiple robots, or improve work efficiency through cooperation of multiple robots [2]. Since the research on path planning, self-localization, navigation and other algorithms of humanoid robots and vision technology all need platforms to verify the results, the humanoid robot platform has become the most basic link in hot research [3].As a complex multi-degree-of-freedom system, robots need to effectively use their multi-sensor information to sense the external environment and their own state changes, and adjust their motion actuators. Therefore, their control systems need to have high reliability and real-time. Sex [4]. People are not only satisfied with industrial robots engaged in traditional types of work, but also hope to have service robots that can work in social services.

For the motion control of multiple robots, centralized and distributed are two different system design ideas. Compared with centralized control, distributed control systems have more flexibility and more robustness, and the task of high efficiency and higher fault tolerance [5]. Distributed control is a typical and versatile multi-robot coordination problem and is the basis for many multi-machine coordination problems. The many advantages of humanoid robots are destined to play a pivotal role in the fields of environment, military and industry. In different mission requirements, the shape of the distributed control and the degree of rigor of maintaining the distribution are different, so the requirements for the environment are also different [6]. When each task and relationship are determined by some mechanism, the problem becomes how to keep the motion coordination among robots, that is, multi-robot coordination. By means of dynamic feedback linearization, the wheel model with nonholonomic constraints is transformed into two second-order integral models to study the distributed control problem of wheel type [7]. The decision-making and action of each individual in a group are independent, but there is a wide range of altruistic cooperative behavior within the group. Based on automation technology, this paper analyses the design of distributed control system for humanoid robot.

2. Motion Mechanism and Sensor System

The control of humanoid robots can adopt various control methods according to the actual working conditions. From simple programming automation, small computer control to microprocessor control, the structure of the robot control system can also be very different. In reality, it is often necessary for multiple mobile units to move from the initial position to a specified target position or roam within a specified area in the environment where obstacles exist. In intelligent groups, there is relatively distributed control between individuals. Compared with the external environment, there is macro distributed control in clusters as a service tool for human beings. Humanoid robots can serve human beings in daily life and work instead of human beings in dangerous environments [8]. In the distributed control process, there must be a reference point. Different robots are located at different relative positions of the reference point, thus forming a certain distribution. In actual network transmission, with the change of effective distance between receiver and transmitter, the interaction weight of communication topology is always dynamic. For adding new join edges and changing their topological structure, the rigidity of the graph will not be affected. Behavior-based controllers consist of a series of actions, i.e. simple basic actions. The accuracy and real-time of information are very important, so the design of multi-agent positioning system is the key problem.

Each behavior has its own goal or task, and its input can be used as the sensor information of the robot or the output of other behaviors in the system. Accordingly, the output of each robot is sent to its actuator to control the distributed control of the robot. Because of its particularity, multi-robot vision positioning must be able to transmit information anytime and anywhere, monitor and analyze data accurately, and achieve efficient interaction through the network. Data acquisition, visual positioning and data receiving module transmit data through interface. The data format is shown in Table 1.

Table 1 Data format

Name	Length
Starting mark	2
Data length	6
command word	7
Data section	12
Termination code	8

The distribution of humanoid robots is regarded as a virtual rigid structure through the virtual structure method, and each agent is regarded as a point with a fixed relative position on the rigid structure. When a plurality of obstacles are superposed on each other and the robot performs distributed control, the superposed obstacles need to be regarded as a large virtual obstacle whole. As shown in Figure 1.

The control system software is the core of the humanoid robot platform, which is directly related to the stability, real-time and robustness of the humanoid robot operation. As the main control unit of the lower computer, its function is to convert the control commands issued by the upper computer into the speed and direction control signals corresponding to the respective motors, and output them to the motor driver to realize different forms of motion of the humanoid robot. The task processing module is the dispatching center, which is responsible for coordinating the work of each module of the business layer. It accepts user commands from the command processing module and environmental information from the global information module [9]. In the positioning process, firstly, multi-agent distributed control image information is collected by camera. Then the image is inputted into the host computer. The image is positioned by image information acquisition, image color recognition, dynamic tracking, data communication and other steps of the positioning software. Coordination execution layer is mainly responsible for joint servo control of robot. In order to improve the real-time and stability of robot, several agents are proposed to realize the function of coordination layer. In order to adapt to the complex environment for autonomous motion, the required perception system is more complex.

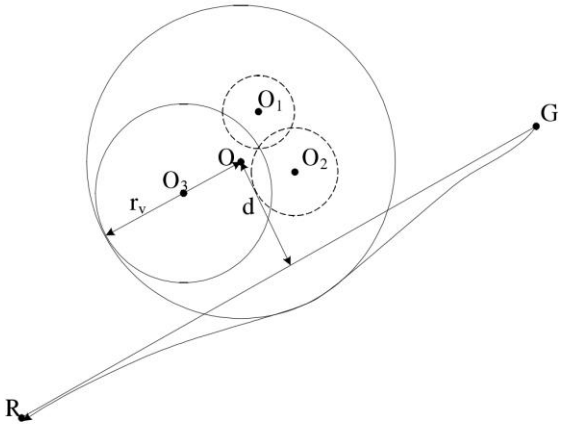

Figure 1 Distributed control trajectory of the robot when obstacles are superimposed

3. Design of Control System for Humanoid Robot

3.1 Requirements for Control System of Humanoid Robot

In the multi-agent positioning experimental system, the function of the controller module is to receive the agent position and environment information, make information decisions and issue control instructions. The main controller first receives various sensor data acquired from the co-controller and mobile position information acquired by the positioning computer. The control system structure of humanoid robot can be divided into centralized control, hierarchical control and distributed control. In order to improve the stability, real-time and developability of humanoid robots, the processor of the control unit is required to have high processing speed [10]. It is difficult to quantitatively describe and analyze many characteristics of distributed control, such as stability and convergence speed. There are two ways to share spectrum between master and cognitive: spectrum underlying and spectrum coverage. There are many cognitive and existing in cognitive radio networks, and each cognitive spectrum allocation depends on the cognitive base station for unified allocation. The success rate varies with the number of cycles as shown in Table 2.

Table 2 Success rate varies with the number of cycles

Number of calculations	Success rate of cue function(%)
3000	81.85
3700	83.21
7000	83.68
8000	88.43

In the case of being unaffected by occlusion obstacles, the agent will be distributedly controlled in the direction of the target point under the guidance of the target point. Select the repulsion potential function between the agent and the obstacle:

$$w_j^i = \frac{\frac{1}{(EP_{LR}^{ij})^2}}{\sum_{j=1}^{k} \frac{1}{(EP_{LR}^{ij})^2}}, \ j \in (1, k) \tag{1}$$

The potential field function between agents can be defined as:

$$HWt = \frac{\sum_{i=1}^{N} D_i(x)}{N} \tag{2}$$

Therefore, the agent is subjected to the potential field control:

$$V_{id} = wV_{id} + c_1 r_1 (P_{id} - X_{id}) + c_2 r_2 (P_{gd} - X_{id}) \tag{3}$$

Considering the uncertainty of the network and the relationship between the topological connection weight and the distance between the agent nodes, the traditional fixed connection weight topological map obviously cannot reflect the communication quality. Figure 2 shows the consistent distributed control state of the agent.

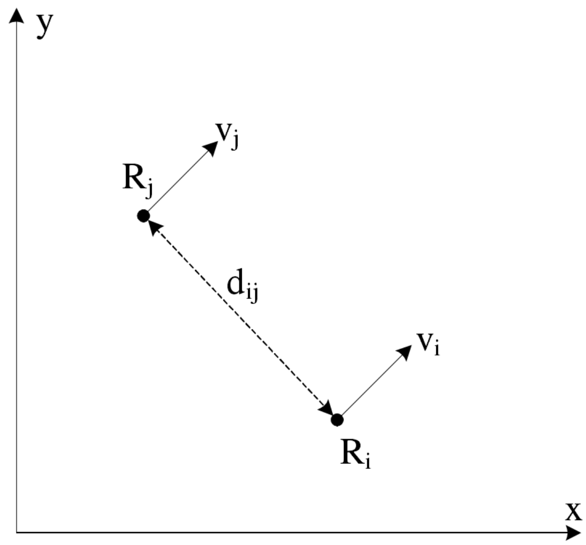

Figure 2 Consistent distributed control state of the agent

For individual agents, the optimal path to be found is along the negative gradient direction of the artificial potential field, that is, the direction in which the function drops fastest. Considering that wireless communication is affected by multipath fading, shadowing and distance variation between transmitter and receiver, it is different from the traditional topology model with fixed connection weights. The receiving probability is introduced to establish a new model of interactive weighted communication topology, which is more in line with the actual situation. The connection weight of the new model changes with the change of the distance between the agent nodes. The main controller carries out comprehensive analysis according to the position information, sensors and other information, and sends the moving control speed and angular velocity information to the distributed control system.

3.2 Gait Planning of Humanoid Robot

Humanoid robot is a complex system. The normal working environment is full of sudden obstacles, which makes it difficult for the system to realize stable movement. In order to realize the dynamic walking of humanoid robot, it is necessary to carry out dynamic modeling, gait control and stability control algorithm design for the robot. To ensure the stable walking of the humanoid robot, the real-time performance of the control system must be guaranteed. Not only the control period must be shortened, but also the fixed time interval must be guaranteed. When humanoid robot works in actual environment, it obtains external and internal information through sensors, and uses adaptive fuzzy logic control to eliminate joint angle error so as to ensure the stability of the system. Assuming that the adjacency map corresponding to the group is connected, then all the individuals in the group will avoid the environmental obstacles to reach the destination, and finally form a stable cluster distributed control if the actual working environment and the preset working environment have a large gap. The adaptive neural network adjusts the parameters of the fuzzy controller online to ensure the stability of the system. In a behavior-based approach, a single agent only needs information about neighbor agents, which is essentially a distributed control method that is not affected by the size of the agent. When there is no obstacle appearing on the agent distributed control path, the agent directly performs distributed control to the target position.

4. Conclusion

Humanoid robot technology is a research hotspot with extensive academic value and application prospects. Research on humanoid robots has achieved many remarkable results, but mainly stays in the theoretical and simulation stages. The research of application system based on humanoid robot is not only the premise but also the ultimate goal of theoretical research. Based on the development history and important achievements of humanoid robots, this paper aims at realizing the versatility and good scalability of humanoid robots for the humanoid robot system with many degrees of freedom, real-time and high reliability. Platform, analysis and design of humanoid robot distributed control system. For the stable walking of humanoid robot, the main control system based on real-time operating system is indispensable. In order to ensure the stability and real-time of humanoid robot walking, we should also implement as few functions as possible under the real-time kernel module. Therefore, the main control system based on time-sharing system is also indispensable. Subsequently, based on this study, we will study how to integrate multiple sensors and map building algorithms to realize the automatic navigation of humanoid robots, so as to make the functions of humanoid robots more perfect.

References

[1] Radford N A, Strawser P, Hambuchen K, et al. Valkyrie: NASA's First bipedal humanoid robot[J]. Journal of Field Robotics, 2015, 32(3):397-419.

[2] Lei J, Song M, Li Z N, et al. Whole-body humanoid robot imitation with pose similarity evaluation[J]. Signal Processing, 2015, 108:136-146.

[3] Gams A, Jesse V D K, Dzeladini F, et al. Real-time full body motion imitation on the COMAN humanoid robot[J]. Robotica, 2015, 33(05):1049-1061.

[4] Robins B, Dautenhahn K. Tactile Interactions with a Humanoid Robot: Novel Play Scenario Implementations with Children with Autism[J]. International Journal of Social Robotics, 2014, 6(3):397-415.

[5] Zaraki A, Mazzei D, Giuliani M, et al. Designing and Evaluating a Social Gaze-Control System for a Humanoid Robot[J]. IEEE Transactions on Human-Machine Systems, 2014, 44(2):157-168.

[6] Wainer J, Robins B, Amirabdollahian F, et al. Using the Humanoid Robot KASPAR to Autonomously Play Triadic Games and Facilitate Collaborative Play Among Children With Autism[J]. IEEE Transactions on Autonomous Mental Development, 2014, 6(3):183-199.

[7] Sheng P, Hu C, Cui Q, et al. Development of Distributed Control System for Neutral Beam Injector on EAST[J]. Plasma Science and Technology, 2015, 17(7):601-606.

[8][Alorda B, Pujol-Nadal R, Rodriguez-Navas G, et al. Collaborative distributed sun-tracking control system for building integration with minimal plant area and maximum energy-conversion efficiency[J]. International Journal of Electrical Power & Energy Systems, 2015, 70:52-60.

[9] Mahajan N P, Deshpande S B, Kadwane S G. Design and implementation of an advanced controller in plant distributed control system for improving control of non-linear belt weigh feeder[J]. Journal of Process Control, 2018, 62:55-65.

[10] Duan Y, Luo L, Li Y, et al. Co-simulation of distributed control system based on JADE for smart distribution networks with distributed generations[J]. IET Generation, Transmission & Distribution, 2017, 11(12):3097-3105.