Design and Implementation of Multi-degree of Freedom Dancing Robot

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Abstract. Dual identity of entertaining and competitiveness makes the dancing robot, a kind of humanoid robot, has new features and strong ornamental. Dancing robot is the product of multiple technology integration and has great value in scientific research and market development. It can simulate human movement like go forward, move back, turn around, stride, lie down and have been shown successfully in a number of occasions like exhibition and performance. A dancing robot design system, which has 16 degrees of freedom, can complete multiple complex dance actions such as dancing displays. The implementation system achieves the control of the hardware implementation and software programming. The displays played by the dancing robots, which can reveal variety kinds dancing styles, are combined with various kinds of music style.

Keywords: Dancing robot; multiple degrees of freedom; structure design.

1 The overall effect design

As a kind of important humanoid robot [1-3], many interesting studies have been put forward in last twenty years. Inamura et al. [4] proposed a framework of imitation, called mimesis loop. Pollard et al. [5] developed a method to import human dance motion into a robot. Kanehiro and Kaneko [6] developed a human-sized robot who can accomplish simple dancing motion.

Design and implementation of dancing robot generally go through three steps. First one is the overall effect design which mainly completes the overall planning and design flow chart. Next one is the overall structure of the system design. The overall structure of the system includes both choices of mechanical structure and drive source. The last one is system control and implementation which includes the respectively design of hardware and software about control system. The following will elaborate each part in detail and introduce multiple degrees of freedom dancing robot design and implementation process.

The beginning part of robot overall effect design is the overall planning of project. The overall effect design mainly includes four steps of design, namely, creative scheme, original design, detailed design and production debugging. During the creative scheme part, we should consider the whole robot integral modelling and design

rules of the theme synthetically. According to the given topic of the dancing robot, we stimulate design inspiration and complete the preliminary creative solutions, then through analysing the scheme feasibility of the project we complete the discussion sessions of the creative scheme. Next step is the original design of the dancing robot. During this part, we mainly design the simulation model of dancing robot by motion simulation and determine the performance scheme. Next part is detailed design step which includes mechanical design, control design, appearance design and motion programming. The last part is production debugging, complete prototype production, program loading and the final debugging [7].

2 The framework of system design

The framework of the system design for dancing robot comprises mechanical structure, the drive source selection, perceived system and control system. Every part of the framework of system design is important. The mechanical structure shows the degrees of freedom of dancing robot. The driving source selection contains the best choose of driving source. The control system includes the hardware and software system. Each part will be introduced in the follow article. Fig.1 shows the framework of system design.

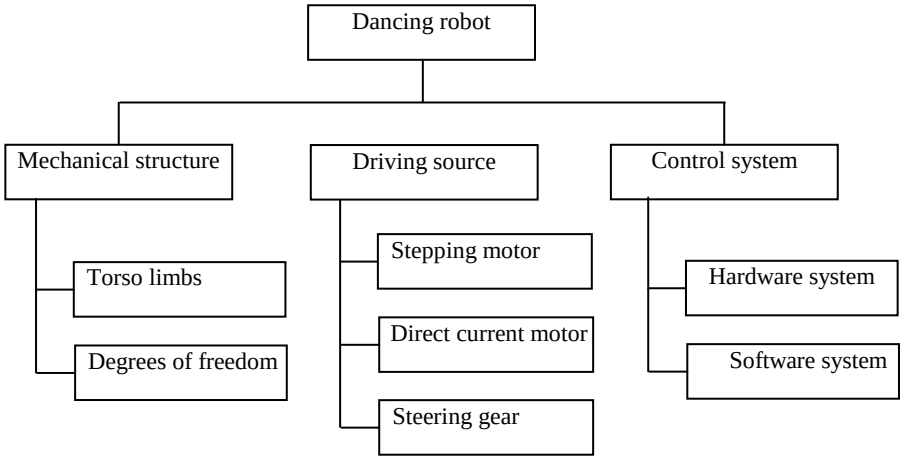

Fig. 1 The framework of system design

2.1 The design of mechanical structure

The mechanical structure is the operative parts of the dancing robot, degrees of freedom is the important indicator of measuring adaptability and flexibility of dancing robot, under normal circumstances, the degrees of freedom is equal to the number of

robot joint. The dancing robot's action is through a combination of movement of each joint to achieve. The design of the dancing robot has 17 degrees of freedom in total, 1 degrees of freedom of the head, 2 degrees of freedom of the shoulder, 1 degrees of freedom of the elbow, 2 degrees of freedom of the crotch, 1 degrees of freedom of the knee, 2 degrees of freedom of the ankle respectively. Among all the degrees of freedom, 2 degrees of freedom stands for the freedom of lateral rotation and turn back and forth, as for the 1 degrees of freedom, it means the freedom of turn back and forth.

Detailed diagram as follows, in the Fig.2, ○ stands for the degrees of freedom of turn back and forth, □ means the degrees of freedom of lateral rotation.

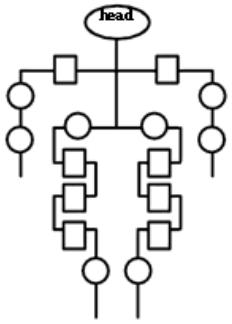

Fig. 2 The mechanical structure of dancing robot

2.2 The selection of driving source

In the part of mechanical structure design of dancing robot, we identify the distribution degrees of freedom of each joint. Next step we shall match the appropriate driving source for each joint of dancing robot, which is drive motor. There are three common drive motor used in the dancing robot at present, which are stepping motor, direct current motor, steering gear. Three kind drive motor each has its advantages and disadvantages, and they also have different scope of application and can be used in various kinds of dancing robot.

Among them, direct current motor has a lot of merits, such as lower power consumption and large torque, but the brush of direct current motor is easily abrasion and easy to form sparks. So direct current motor normally used for closed-loop control system. Stepping motor’s drive multiple to be open loop control. Stepping motor’s control is simple but has little power, usually to be used in lower precision and small power robot system. Steering gear’s control is accurate and has smaller torque.

With the comprehensive considering of the structure, weight, volume, performance, field and action, we finally determined the steering gear which has accurate position and angle control ability as the drive motor for this time designed biped 16 degrees of freedom dancing robot.

Table 1 Comparison of different motor's characteristic

Drive motor type	Advantage	Disadvantage	Application situation
Stepping motor	Precision speed control Multiple type Simple interface	Small power Large bulk Complex control	Light duty robot
Direct current motor	Large torque Easily purchase Large power	Little electric current Lower accuracy Assembly difficult	Large scale robot
Steering gear	Within the band gear speed reducer Simple interface Middle power system Cheap price	Less torque Low load Small range of regulation	Small sized robot

2.3 Implementation of system control

In the dancing robot control system, it includes hardware control system and software control system. Dancing robot should implement dancing function, so the hardware system is the foundation of the dancing robot, while the software system is the vector of dancing robot; both of them are complementary and indispensable for each other.

The dynamics of dancing robot can be described with the following formula.

$$Q = F_Q\left(q_1,\cdots,q_n,\dot{q}_1,\cdots,\dot{q}_n,\ddot{q}_1,\cdots,\ddot{q}_n\right) \tag{1}$$

In the formula, q_i (i=1,…, n)is a group of independent variables of location of various parts of dancing robot. Q stands for the driving force in the joints. $\dot{q}$ and $\ddot{q}$ generalized coordinates q first and second order derivative, that is, its velocity vector and acceleration vector. F_Q is on behalf of a known q/ $\dot{q}$ / $\ddot{q}$ and a set of algorithms for calculation of Q based on the initial state of the various parts of the joint. Set vector $d=(x,y,z)^T$, vector operator $\tilde{d}=\begin{bmatrix}0 & -z & y\\ z & 0 & -x\\ -y & x & 0\end{bmatrix}$.

For n degrees of freedom, the linear velocity and angular velocity of mass center of connecting rod *i*.

$$\begin{bmatrix}v_c^i\\ \omega_c^i\end{bmatrix}=\begin{bmatrix}E & -\tilde{p}^i\\ 0 & E\end{bmatrix}\begin{bmatrix}v^i\\ \omega^i\end{bmatrix} \tag{2}$$

Among them, v^i / ω^i and v_c^i / ω_c^i are the linear and angular velocities of axis and centroid of dancing robot connecting rod *i*. E is 3 × 3 unit matrix. p^i is the vector from the connecting rod *i* joint axis to centroid in the connecting rod *i* system.

The joint speed V^i of connecting rod *i* expressed as,

$$V^i = \hat{S}_{i-1}^i V^{i-1} + \hat{N}^i \dot{q}^i \tag{3}$$

Among them, $\dot{q}^i$ is the angular velocity of dancing robot joint *i*. $\hat{N}^i$ = [0 0 0 0 0 0 1] $^{\mathrm{T}}$, $V^i = \begin{bmatrix} v^i \\ \omega^i \end{bmatrix}$, $\hat{S}_{i-1}^i = \begin{bmatrix} R_{i-1}^i & -R_{i-1}^i \tilde{l}_i^{i-1} \\ 0 & R_{i-1}^i \end{bmatrix}$.

Among them, R_{i-1}^i is the rotation matrix that connecting rod system $i-1$ relative to connecting rod system *i*. l_i^{i-1} is the express in the $i-1$ connecting rod system that the $i-1$ connecting rod system origin to the *i* connecting rod system origin. $\hat{S}_i^k$ has the following features, $\hat{S}_s^m \hat{S}_p^s = \hat{S}_p^m$, $\forall m, s, p \subset n$, and $\hat{S}_m^m = E$, E is the unit matrix.

The main control board parameters of this time designed dancing robot are as follows: internal memory, 56KB; MR-C3024 robot controller: dimension, 50x60x1.5mm; CPU, Atmel Company ATMEGA 128; flash memory, three signal ports; the internal placing eight A/D channel conversion port; the feasibility LCD drive; the six times frequency multimedia sound player; the inner placed ultrasonic interface; the infrared remote controller which send control commands; the high speed serial communication; a tool can be used to control computer software; built in 40 ports can be realized digital input / output; ROBOBASIC v2.0 programming language.

On the aspect of hardware control, the MR-C3024 robot controller as the specialized robot controller can control 24 steering gears at most; it has the advantages such as convenient control ability and high scalability. The combination of the ATMEGA 128 CPU chip and the MR-C3024 robot controller lays the foundation for subsequent robot control programming and provides the good conditions. Tab.2 shows the material object picture and detailed parameters of MR-C3024 robot controller.

On the software programming aspect, ROBOBASIC v2.0 programming software provides powerful robot programming environment and its programming sentence style is similar to Basic programming language [8]. Among all the instructions, the instructions which specially control robot include motor control command, motor grouping command, analog signal processing command and external communication etc. ZERO command is used to setting the motor angle of the normal standing robot. Move command is applied to enact certain group of robot motors rotating to presupposition value at the same time. Speed command can set up the specified speed for robot motor of the Move instruction. PTP command is used for implementing motor synchronization control. ERX and ETX commands realize acceptance and transmission of wireless signals.

Table 2 Parameters of MR-C3024 robot controller

Model	MR-C3024
Picture	
CPU	Atmel ATMEGA128 8bit RISC
I/O Ports	24 I/0 ports
Servo Control	24
PWM DC Motor Control	3
A/D Conversion Channel	8ch
Program Memory	32Kbytes
IR Remote Control Reception	Yes
Bluetooth Control Reception	Yes
Transmitting Bluetooth	Yes
Common Features	LCD Module Control
	6 Octave Piezo(music, voice)
	RS-232(UART) Serial Communication
Misc	Direct Serial Control
	Robot Programming: ROBOBASIC v2.0

3 Conclusions

The dancing robot which owns 16 degrees of freedom and is controlled by steering gear can complete multiple complex dance actions. After the hardware control and the software programming, the dancing robot can achieve arrangement combination of complex dancing acting. The pre-establish software program and hardware control to complete the dancing action. Fig.3 shows the performance of the dancing robots.

Fig. 3 The mechanical structure of dancing robot

This paper introduced the design and implementation process of dancing robot in detail. The design plan of dancing robot comprises two major parts of the overall effect design and the mechanical structure design. The implementation system achieves the control of the hardware implementation and software programming. The displays played by the dancing robots, which can reveal variety kinds dancing styles, are combined with various kinds of music style.

The current development of dancing robot has already performed on many public occasions and been widely welcomed, and the dancing robot brings endless joy for people. The future development of dancing robot will tend to study intelligent diversification. The research and development of dancing robot has laid a solid foundation for the research and development for humanoid robots and intelligent robot in the future.

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