Research and Design of Multi-Joint Bionic Robot

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Abstract. According to the various movement patterns of snakes and caterpillars, the body structure of Multi-Joint Bionic Robot is designed and analyzed, and the Multi-Joint Bionic Robot model was printed by ABS material 3D. The multi-Joint Bionic Robot is designed to achieve winding forward, multi-limb reversal movement, turning, curled up and other movements, through the voice signal detection, ultrasonic distance detection to mimic the ears and eyes of the creature. At the same time, for the problem of controlling joints, a control method combining distributed control and centralized control is proposed, and the parallel control method of multi-joint joints is studied. Experiments were carried out on the multi-joint robot body to analyze the force of the Multi-Joint Bionic Robot during the movement, and the smoothness and fluency of the robot movement were realized.

1. Introduction
The research of Multi-Joint Bionic Robot is a relatively active direction in the field of robotics. The research and development of multi-joint robots has become a research hotspot in the field of bionics. Multi-joint bionic robots have broad application prospects in battlefield minesweeping, blasting, ambulance detection, pipeline maintenance, and detection of harsh environments, such as mechanical insects, robotic fish, mechanical crabs, mechanical snakes, caterpillars, and so on. Therefore, it is of great significance to study the movement mode of multi-joint robots. The snake is a very special creature, and its form of movement is very special. The caterpillar's unique way of movement has its own characteristics for the special movement scenes, which attracts the research interest of many scientists. Combining the innovation of snake Winding movement and caterpillar multi-limb reversal movement, the multi-bionic motion posture of the bionic robot is realized, which meets the requirements of the robot for complex terrain motion.

2. Sports research
In different environments of nature, there are different kinds of snakes, and their modes of movement are also different. They can be roughly divided into the following modes of movement: winding motion, telescopic motion and lateral movement. Among the above modes of motion, the most common is winding motion, which has the highest efficiency and the most common form of motion, followed by telescopic motion, lateral motion is relatively rare. Through the analysis of the snake's movement, we can see that the snake's movement can be regarded as a series of waveform transmission, no matter which way of movement, as shown in Figure 1. The YZ plane moves up and down along the Y direction to realize the telescopic movement; the XY plane moves left and right along the Y direction to realize the winding motion; if the YZ plane and the XY plane perform the spatial composite motion in the Y direction, a so-called lateral movement occurs[¹-²].
Considering the convenience of Multi-Joint Bionic Robot design, the design chooses winding motion mode and assumes the transmission of sine wave, so as to know the change of relative rotation angle of each joint in the process of waveform transmission, so as to control the waveform to move forward steadily. Since the multi-joint robot is similar to a multi-link system, it advances through the coordinated action of each adjacent link. We use the Serpenoid curve as an example to plan the motion gait of Multi-Joint Bionic Robo. Serpenoid is a curve that passes through the origin of the X-Y coordinate system. It can be called a winding curve if the following formulas 1, 2, and 3 are satisfied.

\[
\int_0^S \cos(\omega_\sigma) \, d\sigma = 0 \\
\int_0^S \sin(\psi_\sigma) \, d\sigma = 0 \\
\sigma = a \cos(b \sigma) + c \sigma
\]

The three parameters a, b, and c in formula 3 determine the shape of the curve. By changing the three parameters of the Serpenoid curve, the propagation mode and propagation amplitude of the winding curve can be changed, and the propagation direction of the curve can also be changed. According to the definition of Serpenoid curve, the angle of winding motion of an approximate Serpenoid curve robot composed of N joints can be obtained\(^\text{[3]}\).

Caterpillars are moved by multiple limbs. There are a set of limbs in the front and back of the body. The body is first arched (equivalent to the electric symbol "Ω"), and then the hind limbs are not moving (holding the ground or objects). The forelimb leaves the object, the forelimb falls to the ground and grasps firmly, the hind limb moves and grasps firmly, thus repeatedly moves, realizes the goal of advancing. Figure 2 shows the complete multi-joint motion waveform. Assuming that the initial state of the caterpillar is a straight line, the entire process is moved from the tail to the head\(^\text{[4]}\).
3. Structural design
The Multi-Joint Bionic Robot consists of a series of joints. The first three joints are responsible for the robot's head and head movements. Each joint has an independent degree of freedom and each joint needs to be independently controllable. Therefore, each joint has a separate servo motor as the driver, creating a degree of freedom, through the interaction of multiple joints, simulating the Serpenoid curve to push the entire multi-joint robot body forward. The multi-joint bionic robot has a relatively simple tail function and structure, and only needs to assume the role of placing a lithium polymer battery. The function and structure of the multi-joint bionic robot head is relatively complicated. In addition to designing the installation position of the main controller, it is also necessary to consider the installation location of each sensor. As shown in Figure 3 and 4. In addition, the design of each joint also needs to fully reflect the bionic effect[5].

4. Control system design
The basic design idea of Multi-Joint Bionic Robot is to achieve the corresponding motion posture of each joint by changing the relative motion angle between the joints, thus realizing the movement of the main body. Through the study of snake's winding motion, according to the formula of relative rotation angle between each joint, the different motion forms of each joint are calculated, and the continuous winding motion of the robot is realized by controlling the rotation angle of each joint. In the control, a combination of distributed control and centralized control is adopted. The main control unit is expanded by the communication expansion board, and the Steering gear control panel (joint movement), the Ultrasonic module (Eye-like), the Voice control module (imitation ear), and the Motor control module are respectively connected and communicated with the expansion board. Through the communication expansion board, each module is coordinated with the main control unit to realize distributed control of the robot, and the multi-joint steering gear is controlled centrally through the 32-channel servo control board. As shown in Figure 5, the design can meet the requirements of real-time control, while reducing the load on each unit, and the synchronization is also improved[6-7].

![Figure 3. Structural Design of Joints](image1)

![Figure 4. Integral structure model](image2)
5. Control process
The main control flow of Multi-Joint Bionic Robot includes voice signal detection, ultrasonic distance detection, winding forward mode, curl up mode, alert mode, Multi-limb replacement and so on. After the system runs, the program enters the winding motion control state, and continuously scans the acoustic signal and analyses the distance signal collected by the ultrasonic ranging sensor. When the intensity of the acoustic signal exceeds the set threshold signal, the system enters the crouching mode and the alert mode. When the distance from the obstacle in front is less than 30 cm, the system enters the obstacle avoidance mode. The multi-Joint Bionic Robot neck steering gear controls the head to sway left and right, and the ultrasonic sensor collects the distance signals on both sides. After comparison, the steering gear turns to avoid obstacles and continues to move in a winding motion. When the ranging is greater than 30 cm, Multi-Joint Bionic Robot implements forward mode (Winding Forward) and forward mode (Multi-limb replacement) [8]. The complete control flow chart is shown in the figure 6.

6. Conclusion
Drawing experience and conclusions from the research results of Multi-Joint Bionic Robot at home and abroad, the functional analysis is carried out by Multi-Joint Bionic Robot with different fields and functions; Design and manufacture Multi-Joint Bionic Robot independently through 3D printing advanced manufacturing technology, the ABC material printing test enables the Multi-Joint Bionic Robot model to have a certain molding accuracy and mechanical strength. Through the analysis of multi-Joint Bionic Robot model's gait and dynamics, the reasonable parameters of motion curve are selected. Through detailed analysis of multi-Joint Bionic Robot model's moving gait and multi-legged inverted moving gait, the stability of the robot system is improved. The motion gait of the Multi-Joint Bionic Robot is planned according to the existing Serpenoid curve, and the appropriate forward-time Serpenoid curve parameters are set and verified on the Multi-Joint Bionic Robot entity. In the
experiment, the Multi-Joint Bionic Robot has smooth winding motion, fluent movement of multi-limb reversal, and curled up posture standard to achieve the desired goal. Multi-Joint Bionic Robot entity is shown in the figure7.

Figure 7. Multi-Joint Bionic Robot entity

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