Coordinated intelligent manipulator based on exoskeleton

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Abstract. Manipulators have a wide range of applications in telemedicine, deep-sea exploration, remote explosive-removal and prosthesis for the disabled. Based on exoskeleton and voice control, a coordinated intelligent manipulator was proposed in this paper. The main design scheme, attitude angle data acquisition and data processing methods were given, and the final test results were obtained.

1. Introduction
In 1963, bionic manipulator was developed as a prosthesis product. With the development of science and technology, manipulator gradually replaced manual work to complete some simple, repetitive and harsh work, which can be even applied to long-range explosive ordnance disposal, deep-sea exploration, special operations etc[1]. However, they can only complete a single action for most manipulators. For example, Zhang Chao, Shan Xin, Cui Guoli and Li Jinquan made an industrial manipulator structure design with Four DOFs (degrees of freedom)[2]. It is composed of a big arm and a holding clip, which not only lacks DOF, but also loses the multi-system coordinated control of the manipulator, so it is often helpless in the face of different control objects or complex action execution. Therefore, it is of great significance to study a multi-system and coordinated exoskeleton manipulator, so that it can realize the conversion of control mode according to different working environments.

2. Content

2.1. Design Schemes
This manipulator is mainly composed of somatosensory control system and voice control system. The somatosensory control system mainly adopts Mpu6050 six-axis movement processing module and flex sensor to solve the problem of data acquisition, and establishes remote connection through Hc05 Bluetooth module. Atmel AVR ATmega 328 chip is responsible for the main data fusion as the host. The slave Arduino is mainly responsible for receiving the data of the host and driving the power components. The voice control system remotely controls the slave through the voice recognition App on the mobile phone. The dual system can realize real-time conversion and adapt to different working environments.
2.2. System Hardware Design Scheme
Somatosensory control system mainly solves the problem of real-time synchronization of hands, and adopts exoskeleton bionic technology. The Mpu6050 six-axis movement processing module and a plurality of flex sensors (Figure 1) are embedded at the sending end of the host for collecting the posture information of human arms and fingers. Atmel AVR ATmega328 chip with high performance and low power consumption is used to collect and process information. Mpu6050 can collect the attitude data of the arm, and send the final data to Atmel AVR ATmega328 chip after processing and fusing the angular velocity data and acceleration data. The finger part collects the posture of the finger through flex sensor[3]. The control module can convert the resistance change of the flex sensor into voltage change, and then convert the voltage change into the rotation angle of the steering gear. The information is sent to the driving end through Bluetooth Hc05, and the driving end Arduino processes the received information, so that the manipulator can synchronize the actions of the human hand.

The voice control system uses the self-designed voice recognition APP and Bluetooth to establish a connection with the driver, and send voice information to the driver. Similarly, the drive end Arduino processes information and drives the manipulator to realize complex hand movements. The system structure is shown in Figure 2.

![Figure 1. Flex sensor](image1)

![Figure 2. System structure](image2)

2.3. System Software Design Scheme (Figure 3)

2.3.1. Attitude Angle Acquisition
MPU6050, a six-axis movement processing module, can collect the attitude angles of arms, namely Yaw, Roll and Pitch. MPU6050 is equivalent to the input end, which is based on three-axis gyroscope sensor and three-axis acceleration sensor. The measured quantities are angular velocity and acceleration. The angle can be obtained by integrating the acceleration into angular velocity, and then integrating the angular velocity. Secondly, the acceleration here is gravity acceleration, not movement acceleration. In addition, gravity and velocity sensors in the stationary time of the gravity is not affected by the
movement acceleration. Therefore, the value of gravity acceleration is more accurate. When the gravity acceleration sensor is stationary, the horizontal acceleration can not be obtained, so the Yaw data can be measured by the geomagnetic field sensor.

After obtaining the attitude angle, the attitude angle is changed by Euler angle-Yaw, Roll and Pitch.

2.3.2. Quaternion
Quaternion is a representation of rotation, similar to Euler rotation, but a quaternion is a quantity in four-dimensional space, and a quaternion can be expressed as \( q = w + xi + yj + zk \), where \( w \) is the real part, \( i, j, k \) are the imaginary part, and \( x, y, z \) are the coefficients\(^{[4]}\).

A quaternion can be thought of as a more general form of a vector and a real number. A vector can be thought of as a quaternion with a real part of 0, and a real number can be thought of as a quaternion with an imaginary part of 0. The operational properties of the above quaternions are also more general forms of the operational properties of real numbers or vectors.

2.3.3. Kalman Filter Algorithm
In fact, Kalman filter repeatedly processes the observed values and predicted values measured by Mpu 6050. In the attitude calculation process of MPU6050, with the continuous integration of gyroscope, error drift will inevitably occur, and the Kalman filter algorithm for correcting error is the fusion of accelerometer and magnetometer observations\(^{[5]}\).

The core idea of the code is to obtain the rotation angle of the four-axis sensor by using the integration of the gyroscope, and then correct the integration result of the gyroscope by calculating the proportion and integration of the accelerometer.

We establish geographical coordinate systems X, Y and Z in space, and define three-axis Kalman variables of float type in code. A point in the recording space is X, and the angle \( \alpha \) rotated around the Z axis first, then \( \alpha \) is the angle between X and X axis. Because X has a direction, we can get the third-order matrix of X. After calculation, the final matrix is cosine matrix, and \( \gamma, \theta, \phi \) are Euler angles. Euler angle is the most intuitive, namely Pitch, Roll and Yaw. Generally, the rotation sequence is Yaw first, then Pitch, and then Roll reacts to the coordinate axis, namely first rotate around the Z axis, then rotate around the X axis, and finally rotate around the Y axis.

2.3.4. Software Design of Flex sensor
At the collecting end of the host computer, a flex sensor is initialized, and the flex sensor is deformed due to the bending of fingers, thus changing the resistance, thus affecting the voltage after the resistance changes. At the collecting end, analog-to-digital conversion is carried out to process digital signals. At this time, the five-digit array is received in the program, and the five-digit array is stabilized by anti-shake algorithm. After processing, five groups of stable data are transmitted through Bluetooth, and five groups of stable data are received at the receiving end, and then the data is stabilized by anti-shake algorithm. Use anti-jitter algorithm. The stable data is transmitted to the steering gear driving function as the parameters of the steering gear driving end. At this point, the synchronization between fingers and bionic manipulators is achieved.
3. Final TESTING
The test site is Shengle Campus of Inner Mongolia Normal University. Posture collection has been preliminarily realized, finger bending can realize full grip, and voice control can be accurately implemented.

- Rotation speed: 0.16s/60°
- Actuator torque: 20kg. cm
- Use times of flex sensor: > 1 million times
- MPU6050 Speed: 2000°/s
- Speech recognition transmission speed: 1-2s
- The arm Yaw can achieve 270°
- The finger part can be fully gripped

The sampled data of the test part is shown in Figure 4. Open the serial port monitoring diagram, swing the arm or bend the flex sensor will clearly see the sampling line fluctuating up and down. When our arms and fingers are still, the sampling line will remain on a horizontal line, and there will be no large fluctuations, only slight jitter. Because sampling will have an error of ±1°.
4. CONCLUSION

Currently, there are many manipulators with different types and functions on the market. However, the control mode is relatively simple and can only be limited to specific working conditions. This paper introduces a new coordinated intelligent control system based on bionics, somatosensory and voice, which greatly improves the performance of the manipulator. Compared with the previous products, the control system is more diversified, and the actual design and testing are carried out, which provides substantive basis and reference for the future research of various types of manipulators. The whole machine is shown in Figure 5.

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