Research on Intelligent Recognition of Intelligent Gloves based on Acceleration Sensor

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Abstract. This paper adopts the wearable smart glove sensor as the data acquisition device. Based on the acceleration-based gesture recognition method, the attitude angle data information is added to improve the recognition accuracy of the smart glove. The collected data is segmented using a threshold model, and then the ant colony algorithm is used for feature extraction. Finally, the hidden Markov model is used to model, train and identify gestures. The results show that the proposed algorithm has a better recognition effect on gestures, especially complex gestures.

Keywords: Gesture recognition; Human-computer interaction; Acceleration sensor; Smart glove.

1. Introduction

Artificial intelligence refers to the intelligence exhibited by a system that is artificially manufactured, usually referred to as intelligence implemented by ordinary computers. As an important part of artificial intelligence, human-computer interaction is a technology for researching information exchange between humans and computers through human-machine interfaces. The ideal way of human-computer interaction is the same way of communicating between people, using the language, gestures and other free and direct way to operate the user interface. As an important implementation of human-computer interaction, gesture recognition technology has become a research hotspot in the past three decades [1].

A wearable sensor-based recognition system generally uses a smart data glove motion sensor to acquire gesture data. The data glove can collect data on the motion data of the gesture, the hand shape, and the bending angle of the finger arm [2]. The advantage of the data glove is that the collected data is relatively stable and the signal processing is simple. The disadvantage is that the equipment is more complicated and expensive, and the utility is relatively low. Motion sensors based on acceleration, geomagnetism, and gyroscopes are not limited by external conditions, and can perform gesture recognition under harsh environmental conditions and in a large spatial range.

2. Intelligent Glove Gesture Recognition Theory based on Acceleration Sensor

2.1 Gesture Definition

Gestures are a form of non-verbal communication that conveys information in visible physical motion, either in combination with speech or separately. Often includes the movement of the hands, arms, face or other parts of the body. In the 1940s, Quek et al. classified gestures according to their functions from the perspective of human-machine interface, as shown in the following figure.

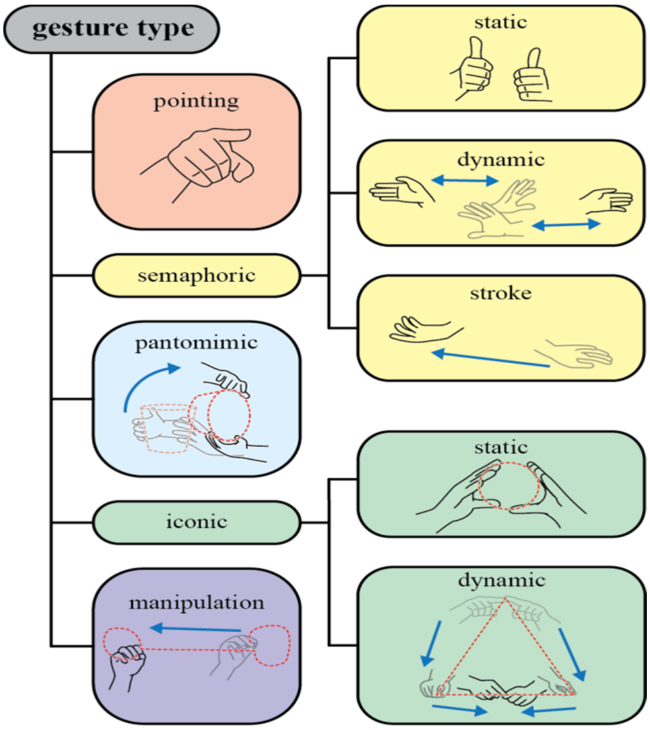

Fig. 1 Classification of gestures

2.2 Gesture Modeling

Gesture modeling is the use of the characteristics of a gesture to build a model, and uses the model to represent the process of the gesture. Gesture modeling is the basis of gesture recognition, and gesture recognition is a process of classifying according to an established gesture model [3]. This paper mainly models dynamic gestures. From a spatial perspective, dynamic gestures are a trajectory of the hand in the air as shown.

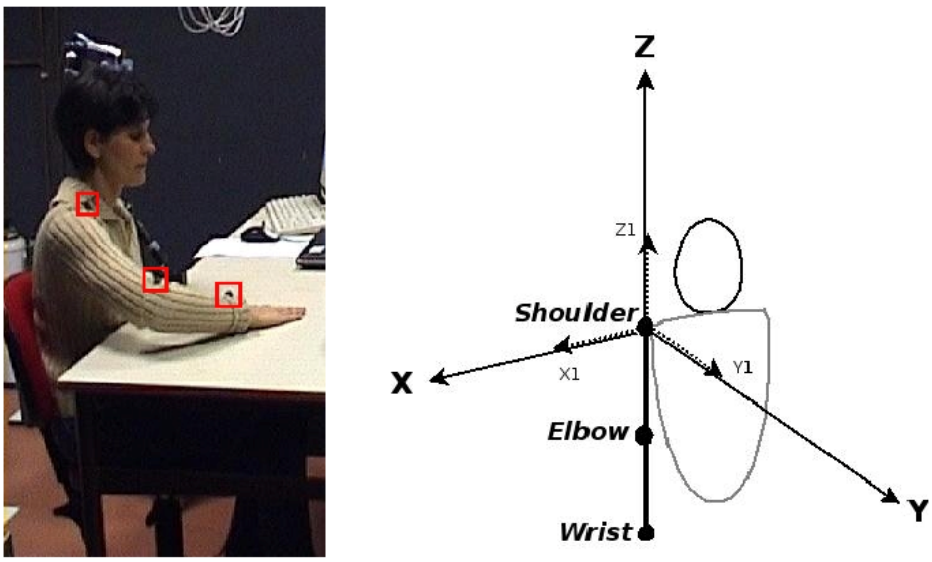

Fig. 2 Gesture trajectory modeling

The gesture track consists of a series of ordered three-dimensional points, namely:

$$T = \{p_1, p_2, p_3\} \tag{1}$$

Where $p_i = \{x_i, y_i, z_i\}$ is a point in 3D space, dynamic gestures not only have spatial properties, but also have time properties, so we introduce the velocity property $\overline{v_i} = \{\overline{v}_{ix}, \overline{v}_{iy}, \overline{v}_{iz}\}$ of the spatial coordinate points. The speed is differentiated from the time to get the acceleration of point p_i.

$$\overline{a_i} = \frac{d\overline{v_i}}{dt} \tag{2}$$

In the above trajectory model, the hand is seen as a zero-dimensional point. But as an entity, the hand is a rectangular parallelepiped structure, and the data collected by the sensor also acts as a cuboid. Therefore, we also need to introduce the parameter $\phi_i = (\theta, \gamma, \varphi)$ of the attitude angle, where θ, γ, φ is the angle between the palm plane and the human axis and each plane [4]. The angular velocity $\Omega = (\omega_\theta, \omega_\gamma, \omega_\varphi)$ of the palm toward the change is as follows.

$$\omega_\theta = \frac{d\theta}{dt}, \omega_\gamma = \frac{d\gamma}{dt}, \omega_\varphi = \frac{d\varphi}{dt} \tag{3}$$

In summary, for a dynamic gesture G, combined with the trajectory, speed and orientation, plus time constitutes a quad as follows:

$$G : \langle T, V, \Phi, t \rangle \tag{4}$$

For a dynamic gesture, the quad contains both its overall and detailed features. The overall feature is the trajectory of the gesture and the orientation of the palm. The detail features are the velocity and acceleration during gesture expression and the inclination of the palm.

3. Gesture Recognition Method based on Acceleration and Attitude Angle

3.1 Gesture Recognition Process

Gesture recognition is a process of classification that matches the sensor trajectory data collected by the sensor to the model in the model set. According to different gesture categories, gesture recognition is divided into static and dynamic. Static gestures are independent of timing, while dynamic gestures correspond to a timing-dependent trajectory. As shown in the following figure, the object to be recognized by the static gesture is a stationary hand. Generally, pattern matching or other image-based recognition methods are used. The static gesture recognition captures a static image of the gesture. Since it is related to time and space, the recognition of dynamic gestures is relatively difficult, and the object of gesture recognition also changes from static image to dynamic time-dependent acceleration data and attitude angle data [6-7]. The recognition process of a gesture begins with the collection of data, selection, gesture modeling and training, and gesture recognition.

3.2 Data Collection and Preprocessing

The data directly read from the sensor fixed on the smart glove has three defects: the device is not affected by the gravity, the gesture data is continuous without segmentation, and the amplitude of the same action is large or small. Therefore, the following three steps of pre-processing of these defects are required before using the data.

Since it is fully connected, any state in the figure can be reached in one step by other states. The output and self-transition probability in the model is defined as:

$$a_{ij} = \frac{1 - a_{ij}}{N - 1} \qquad \forall j, i \neq j \tag{5}$$

a_{ij} is the transition probability, and N is the number of states of all the removal start and end states. Any of the gesture models can be represented by the model. The forward transition probability is greater than the predefined model probability. Therefore, the model's likelihood value can be used as the threshold for selecting the gesture model corresponding to the given observation model. When the probability value of the observed model is greater than the threshold model, the gesture of the observed model can be determined.

The threshold model and the recognition model of each gesture together form a gesture recognition network that detects the starting point of the gesture from the input data stream, that is, in turn, finds the optimal observation sequence according to a sequence of states, in accordance with the sequence of the predetermined gesture model. When the output probability is greater than the output probability of the threshold model, the end point of a gesture is determined. But usually there is more than one such situation, and multiple end points will appear.

4. Smart Glove System Design

4.1 System Structure and Principle

The system is based on TI's MSP430F5529 microcontroller, which collects data through the data end bend sensor and the nine-axis attitude sensor, and transmits the data to the identification end via the low-power WIFI transmission module. The recognition end also uses the MSP430 microcontroller, which uses an improved algorithm to recognize the degree of bending of the finger and the movement posture of the palm, matching the gesture database in the SD card, and parsing the correct gesture. Finally, the instruction parsed by the identification end is transmitted to the glove end for voice output through WIFI, or the connected peripheral device is gestured by WIFI [8]. The program flow chart is shown in Figure 3.

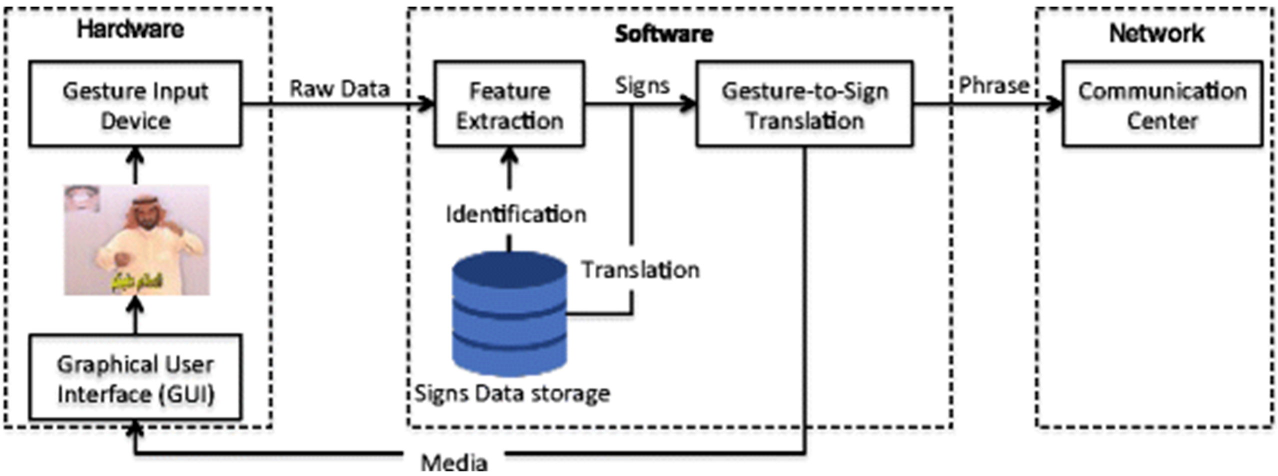

Fig. 3 Structure and principle of intelligent glove system based on acceleration sensor

4.2 Finger Bend Measurement Module

In order to obtain an accurate finger bending posture, the module uses a one-way bending sensor Flx-03. Flx-03 is a simple sensor for measuring the degree of bending. Flx-03 has a total length of 80mm and a measuring length of 60mm. The corresponding resistance is different for different bending degrees. The resistance is 9000Ω in natural state, 180. The resistance is 22000Ω when bent, and it can be used in ultra-thin package. It is fixed on the surface to be tested. In the circuit, the change of the resistance value of the sensor is outputted as a change of voltage, and with the quantized output of the ADC, it is easy to collect and process the bending information.

4.3 Palm Motion Posture Measurement Module

In order to obtain accurate palm movement postures, such as acceleration and Euler angles, the module uses a nine-axis attitude sensor LSM9DS1. The LSM9DS1 is a system chip for motion sensing. It includes a three-axis accelerometer, a three-axis gyroscope, and a three-axis magnetometer. Each sensor has a good detection range. The sensor also includes an I2C serial bus interface with a digital interface that supports both standard and fast modes (100kHz and 400kHz) and SPI serial interface standards. At the same time, it has low power consumption and supports 1.9V-3.6V power supply. Under normal operation, the operating current of the electromagnetic meter is only 280uA; the accelerometer current is 8.4uA; the current of the gyroscope is 1.9mA, in the sleep mode. The current is 8uA. By using the single-chip microcomputer to analyze the data collected by it, it is possible to judge the posture more accurately and then control the corresponding functions.

4.4 Experimental Results

In this experiment, 5 subjects were randomly selected and collected several times for various gestures such as Arabic numerals, 100 common greetings, 76 verbs, and 120 life rankings. The collected data is integrated and filtered, and three sets of data entry databases with the highest repetition rate of each gesture are selected. Use this as the initial model parameter for each gesture. To ensure complete entry of actions, gesture actions are divided into static actions and dynamic actions. The data acquisition period of the static action is set to 150ms, and the data acquisition period of the dynamic action is set to 800ms. After each data acquisition, the data is transmitted to the host computer through WIFI. The host computer system performs software filtering processing on the static motion data to improve accuracy. The dynamic data and the data in the library are compared byte by byte, and the current data and the previous data are software-filtered in units of bytes to improve reliability.

5. Conclusion

The article describes how to use a smart glove to perform activity recognition while simply keeping it in the user's hand. In addition to distinguishing sign language, this method can be used to successfully obtain accurate classification results. The author plans to improve this activity identification task in the following aspects. These improvements include: (1) Learning to identify additional activities. (2) Get training data from more users to improve our results. (3) Extract more complex features based on source time series data [14]. (4) Smart Gloves is part of the “Excavating Wireless Device Sensor Data” project and plans to continue the project. First, other types of sensor data, such as GPS data, will be acquired and mined. In addition, the collected data is applied to tasks other than activity recognition. The author believes that mobile sensor data provides an excellent opportunity for data mining and aims to maximize this Android-based data collection and mining platform.

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