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Gesture Recognition based on BP Neural Network and Data Glove

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***Abstract* – Various devices for hand data collection have been proposed for gesture recognition. In this paper, a method is proposed for gesture recognition based on data glove and BP neural network. This data glove can collect data of the hand and forearm, it gives a comprehensive description of all aspects of arm movement, and BP neural network algorithm is used to process and classify the collected data and compress the data. Experiments show that hand data can be classified effectively by BP neural network.**

Index Terms - Gesture Recognition, Data gloves, BP neural network, data classification.

I. INTRODUCTION

Nowadays, computer has entered into every aspect of our life. With the rapid development of computer and information science, better human-computer interaction has gradually become a hot spot in scientific research [1]. High-tech products and high-quality finished products not only provide convenience and speed for our daily life, but also accelerate the rapid development and research of human-computer interaction. The main method of human-computer interaction is information transmission and interactive operation. The person sends an instruction to the computer, and the computer feeds back the result to the user after completing the corresponding operation. Gesture recognition is one of the human-computer interaction devices. Gesture recognition can be applied to various aspects of life. Gesture is a meaningful human movement that can realize communication and connect upper limbs with human face. It is used to transmit interactive information between human body and environment [2].

In the medical field, the application of gesture recognition can alleviate the medical pressure all over the world [3]. With the full coverage of 5G, gesture recognition can play more important roles in medical treatment. Therefore, research on it is very necessary and it can be more efficient and convenient [4]. On the other hand, gesture recognition will be paid more attention in the field of games in the future. Motion-sensing devices can improve the entertainment level of games, which makes gamers feel more immersive and have more game experience [5]. Therefore, we should pay more attention to gesture recognition, the most important for the collection of hand data.

There are many ways to collect data on the opponent's hand [6]. We can use the color gloves to collect the data of the hands. It can be used to detect and track the hand shape and model the finger joints, but the disadvantage of the color gloves is poor convenience. Somatosensory devices can also be used for collection, but somatosensory devices are less convenient and more expensive [7]. And we can use the camera to collect data, but the camera has high requirements for the algorithm. The advantages of hand data collection through data gloves are small amount of input data, fast recognition speed, high recognition accuracy and it is not easy to be interfered by the outside world [8].

Therefore, this article uses the data glove as the data collection device. The data glove used in this article is researched and used by the author. This data glove increases the elbow angle data collection compared to the traditional data glove, which makes the hand Data collection is more comprehensive [9].

II. WORK PRINCIPLE

The data glove used in this article mainly collects the posture data of the hand and forearm, so 5 bending sensors are installed on the 5 finger parts to detect the bending degree of the finger. The bending sensor is based on the resistance carbon element [10]. As a variable print resistance, the bend sensor has a large shape factor on a thin flexible substrate. When the substrate is bent, the sensor generates resistance relative to the bending radius. The smaller the output radius, the higher the resistance value [11]. Posture sensors are installed in the wrist of the hand and in the elbow to detect the posture of the palm and forearm [12], adding a forearm sensor can collect hand information more comprehensively in order to recognize more complicated gestures in the future. The bend sensor was used to detect the bending of five fingers, and the posture sensor was used to detect the movement of limbs [13]. Fig. 1 is the schematic diagram of the bending sensor.

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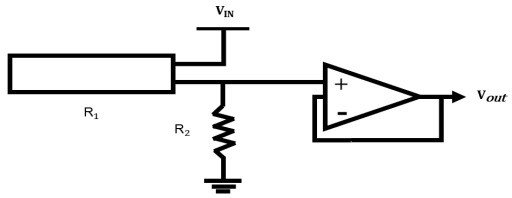


Fig.1 Principle diagram of the bending sensor

The calculation formula of the voltage of the bending sensor:

$$V_{our} = V_{in}\left(\frac{R_1}{R_1 + R_2}\right) \quad (1)$$

The controller used for data collection is the data formula of the analog voltage output by the Arduino mega2560 in the Arduino:

$$a_0 = \frac{R_1}{R_1 + R_2} * 1023 \quad (2)$$

a_0 is the analog voltage output by the bending sensor at the analog port of the controller. When the bending Angle of the bending sensor increases, the resistance value of the bending sensor decreases [14]. The analog voltage divided by the bending sensor decreases, and a_0 decreases. The experimental data glove is shown in Fig.2.

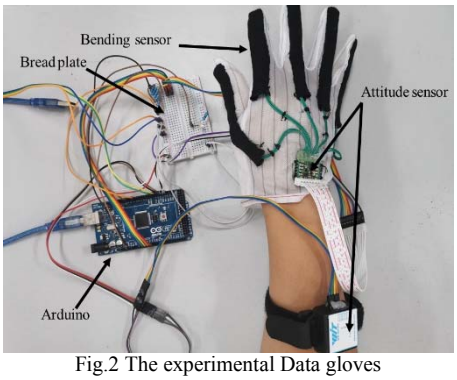


Fig.2 The experimental Data gloves

The Arduino mega2560 control chip receives the data detected by each sensor, and performs the corresponding AD conversion and processing.

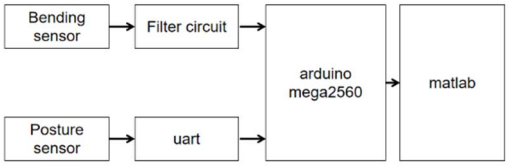


Fig.3 Structural drawing of the data glove

The bending sensor and the attitude sensor each transmit 11-bit data to the Arduino mega2560 controller through the filter circuit and serial communication, and the controller transmits the received data to Matlab for processing through serial communication [15].

The first 5 digits are the 5 analog voltage data of the bending sensor installed on the finger of the glove, the last 3 digits are the 3 Euler angle data of the wrist posture sensor, and the last 3 data are the Euler angle data of the elbow joint, A total of 11 bits of data. For gesture recognition, algorithms such as BP neural network are commonly used to process the original data, because BP neural network is mature in both network theory and performance. Its outstanding advantages are strong nonlinear mapping ability and flexible network structure, and BP neural network has a high degree of self-learning and adaptive ability and fault tolerance ability. In addition, it has the ability to apply the learning results to new knowledge. [16]. The number of middle layers and neurons in each layer of the network can be set arbitrarily according to the specific situation, and its performance varies with the difference of structure [17]. Although only 10 gestures are collected now, more gesture data will be collected in the future, and the training sample is huge. The SVM algorithm is difficult to implement for large-scale training samples. For this situation, this paper uses the BP neural network algorithm as the gesture recognition algorithm [18].

III. Gesture Recognition Design

TABLE I
GESTURE CORRESPONDS TO A SAMPLE OF A SET OF DATA

Gestures	Thumb	Index	Middle	Ring	Pinky	X1	Y1	Z1	X2	Y2	Z2
0	109	88	90	96	69	108.44	43.41	-36.71	-57.32	-26.88	-92.81
1	113	159	99	123	83	93.98	33.29	-23.09	-78.89	-37.67	-43.84
2	120	176	167	122	91	93.64	39.03	88.14	-87.50	-44.81	-50.21
3	121	102	162	162	117	115.74	16.62	-117.06	-74.75	-37.31	-74.73
4	112	173	162	164	130	115.23	5.60	-58.52	-90.68	-31.32	-46.92
5	164	158	165	158	135	93.47	22.63	-76.48	-91.86	-33.96	-40.62
6	152	111	110	130	110	120.76	30.44	-86.96	-96.32	-38.98	-41.71
7	120	142	124	136	129	99.05	0.68	-65.84	-83.56	-27.10	-60.18
8	148	162	106	118	90	88.88	29.55	22.98	-101.82	-28.44	-31.82
9	114	114	90	84	73	100.68	13.94	52.04	-78.18	-36.49	-62.33

Correct recognition of gestures is critical [19]. In this paper, the data collected by the data glove is normalized, and the feature vector output by the neural network corresponds to the digital common gestures from 0 to 9 [20]. Table 2 shows the digital gestures corresponding to each feature vector [21].

TABLE II
DIGITAL GESTURES CORRESPONDING TO EACH FEATURE VECTOR

Feature vectors	Gestures
1 0 0 0	Digital 0
0 1 0 0	Digital 1
0 0 1 0	Digital 2
0 0 0 1	Digital 3
1 1 0 0	Digital 4
1 0 1 0	Digital 5
1 0 0 1	Digital 6
1 1 1 0	Digital 7
1 1 0 1	Digital 8
0 1 1 1	Digital 9

We found that when the testers are not the same person or different genders, even when the same tester makes the same gesture, the sensor values will be very different [22]. In order to increase the diversity of the training set, we will conduct multiple training set samples for multiple individuals. We will select one male and one female operator at the age of 20,25 and 30 to collect training set samples, and each person will collect data for the same gesture for five times [23]. so that each digital gesture would be described by 30 different training samples, increasing Data diversity. Each gesture corresponds to 11-bit data. There are 30 sets of training set for each gesture, a total of 10 gestures. Putting them into a neural network for training data [24].

IV. BP NEURAL NETWORK

Among the methods for recognizing gestures, the neural network method has been widely used [25]. Self-learning and adaptive capabilities are the characteristics of neural networks, and have faster recognition capabilities, and the neural network has strong anti-interference ability and fault tolerance. It can integrate the preprocessing and recognition processes, so the neural network is used for Gesture recognition. Recognition of gestures by using data gloves is a classification process. This paper uses BP neural network for classification and recognition. BP neurons are similar to other neurons, but the difference is that the transfer function of BP neurons is right or wrong. Linear functions, generally the most commonly used functions are logsig and tansig. The BP network is mostly multi-layer, and the information of the BP network flows from the input layer to the output layer, so it is a multi-layer feed-forward neural network. The topological structure of BP neural network model used in this system includes input layer, hidden layer and output layer. The number of nodes in the input layer and the output layer has been determined in the experiment. The most important thing is the number of nodes in the hidden layer. It needs to be calculated and estimated. Existing studies have found that the number of hidden layer neurons and we need the problem solved, the degree of complexity and the characteristics of the data sample are all related. So we determine the number of hidden layers according to the following formula:

$$m = \sqrt{n+1} + \alpha \tag{3}$$

$$m = \log_2 n \tag{4}$$

$$m = \sqrt{nl} \tag{5}$$

In the above formula, m represents the number of hidden layer nodes, l represents the number of output layer nodes, n represents the number of input layer nodes, and α represents a constant between 1-10. The BP neural network is created by Matlab, as shown in figure 4.

The number of nodes in the hidden layer should be less than N-1(N is the number of training samples), otherwise the systematic error of the network model has nothing to do with the characteristics of the training samples and tends to 0, that is, the established network model has no generalization ability and no use value. Similarly, the number of nodes in the input layer must also be less than N-1. These are three empirical formulas. Through these three formulas, the maximum and minimum values are calculated, and the prediction performance of each network is compared step by step. The corresponding number of nodes with the best performance is selected as the number of neurons in the hidden layer, and the number of neurons in the hidden layer is determined to be 5.

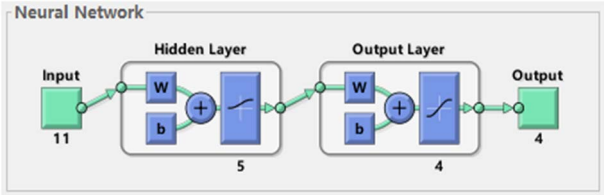


Fig.4 BP neural network

Combined with the BP neural network mentioned above, including the recognition algorithm and training algorithm, the BP neural network is trained before gesture recognition, and their input weights are adjusted. After the training is completed, the data transmitted by the MCU in real time through the upper computer Matlab is put into the neural network. Gesture recognition is carried out on the real-time transmitted data, and the user's hand movement information is finally obtained. Figure 5 is the flow chart of the specific algorithm.

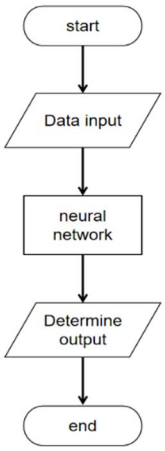


Fig.5 Algorithm flow chart

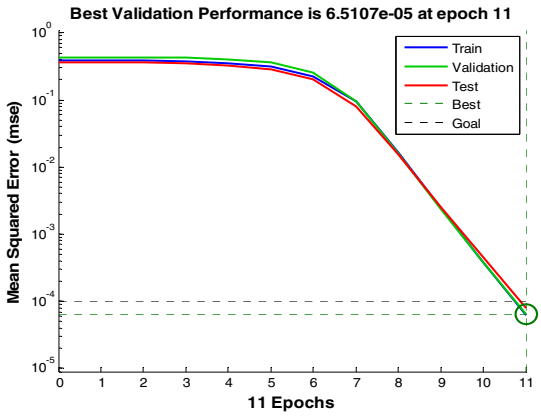


Fig.6 Mean square error gradient graph

Mean square error is the error analysis of the neural network algorithm. In the process of neural network training and learning, MSE as a loss function is relatively easy to understand.

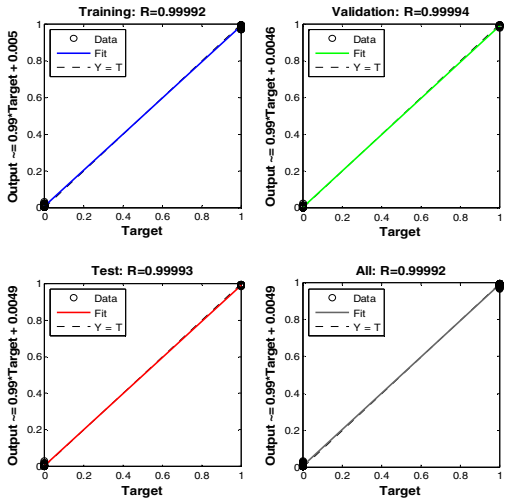


Fig.7 Fitting of various data

The higher the R, the higher the degree of fitting.

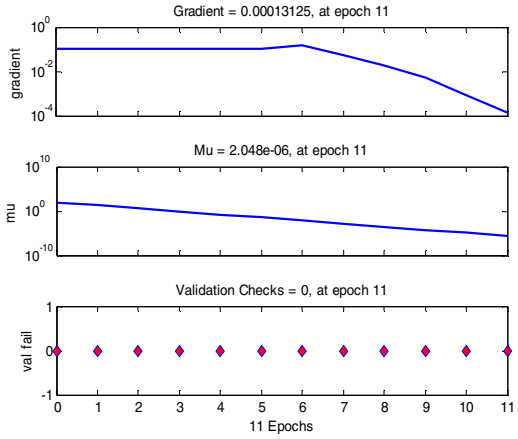
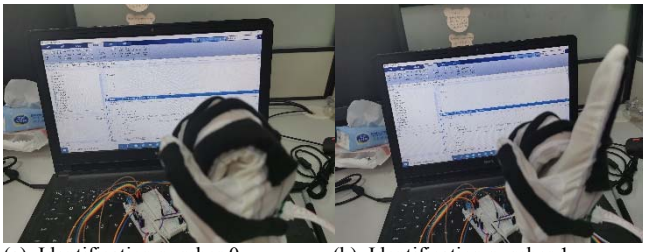


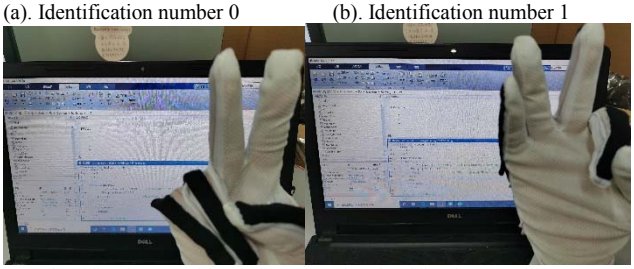
Fig.8 Parameter changes during training

V. CONCLUSIONS

The results of the experiment are reflected in the command line of Matlab. The experiments are the recognition of the numbers 0 to 10. After the BP neural network is trained with the data gloves in the figure, the data of the data gloves are imported from Matlab in real time. Correct identification of numbers 0 to 10. Figure 9 shows the correct recognition of the number 1 to 4 hand gestures. The number 1 was correctly identified when the index finger was extended, and the number 2 was correctly identified when the index and middle fingers were extended. the same is true for the number 3.



(a). Identification number 0 (b). Identification number 1



(c). Identification number 2 (d). Identification number 3

Fig.9 Recognition rendering

This paper uses data gloves to put the data of different operators into the neural network for training and transfers the data of the data gloves to the BP neural network in real time to correctly identify the numbers 0 to 10.

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