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FRIDAY, 17 JUNE, 2005, 09:00

Lounge A : Human Computer Interaction

Lounge B : Military Systems

FRIDAY, 17 JUNE, 2005, 12:00

Poster Presentation II

An ANN Based Electronic Glove for Human-Machine Interaction

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Abstract

A design method for an electronic glove interface which is an alternative to the traditional methods for the human-machine interaction (HMI) is presented, in this work.

1. Introduction

Systems which sense and process human motion are widely used in today's technology. Especially, they are very important for the animation and cinema industry [1-8].

In spite of the high improvements in the technology, any machine needs to operate in interaction with human. The device which fulfills this interaction is named as interface.

As an interface, hands are used at most. They are the most functional organ in the human body. In this respect, perceiving the human hands movements are very important.

In this work, the design of an interface system which perceives and process human hand's movements is considered. To fulfill this need, first an electronic glove is designed. Then, the motion data captured by this electronic glove are digitally coded and transmitted to the computer. Finally, those data are processed by an Artificial Neural Network (ANN) which outputs the simulation of finger movements.

The rest of the paper includes the description of the anatomical structure of human hand, the sensor mechanism of the interface system, hardware structure and the data processing software.

2. The anatomical structure of human hand

A human hand has more than twenty bones and fifteen junction nodes. This complex structure which is shown in Figure 1, spans the space by a dynamic system with 27 DOF.

However the motion capability of human hand is restricted by the interaction between muscles and tendons on these joints. Also some of the junction points are functionally related. These restrictions can be dived into two main groups which include static restrictions and dynamic restrictions. Static restrictions arise from the impossibilities on the structure of joints, whereas dynamic restrictions arise from the interactions of the muscles and tendons of the hand with the tendons and muscles of neighbor units. For example the joint A (Distal Interphalangeal) that is shown in Figure 1 is affected by the movements of joint B (Proximal Interphalangeal) in relation of

$$\theta_A = \frac{2}{3}\theta_B . \quad (1)$$

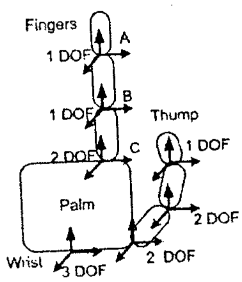

Figure 1. Structure of human hand

3. Flex sensor and processing of data

In the present work, in order to get the digital signals of finger motion, flex sensors are mounted on the glove. Because of the elastic structures of fingers, flex sensors whose resistance varies by twisting are used.

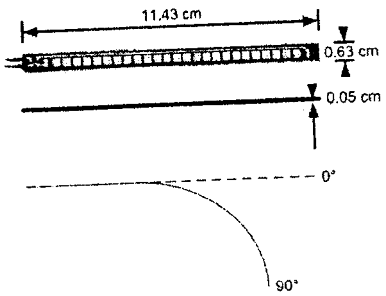

Figure 2. The structure of flex sensor

The flex sensor shown in Figure 2, operates as a variable resistance. The resistance of the sensor is linearly proportional with bending of fingers. The value of the resistance which is about 10KΩ without any bending, may take values up to 35-40 KΩ after bending. In order to measure the resistance value in a wide-banded region in high precision, a Wheatstone bridge is used.

4. The hardware structure of the glove interface

To transmit the hand motion data to the main computer via microprocessor, a structure that is shown in Figure 3 is used

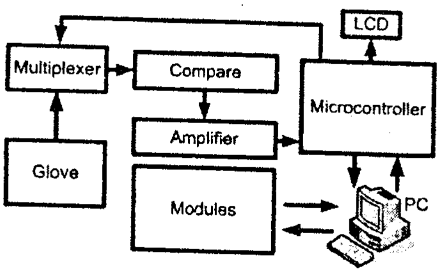

Figure 3. The hardware structure of the system

On the glove, two sensors are mounted for both index and mid fingers. One of the sensors is only affected by joint C, whereas the other sensor is affected by the movements in joints A, B and C. Thus, the glove has five sensors including the one for thumb. In order to map the sensor outputs into the same universe of discourse, a bridge circuit and a power amplifier circuit is used. Instead of using the same circuit five times, a fast analog multiplexer is embedded to the system. In this way the hardware has became more compact and economic. The operation of the analog multiplexer is controlled by a microcontroller.

The microcontroller has two main tasks. First of them is to collect and transmit the data from glove to the computer serially and the second is to transmit the data from the computer to the operator via a LCD display. As a microcontroller PIC family is preferred because of its RISC architecture which reduces the cost and computational time expended. On the other hand, RISC microprocessors are widely used and accepted in industry.

5. System software

The programs that are used by the microcontroller are all coded under C. In this respect, the design time and time elapsed for error pick is significantly reduced.

The microprocessor program, samples the analog signal from the ADC and back up these data in an infinite loop and at the end of each loop the microprocessor transmit these data to the computer via serial port. This infinite loop may be interrupted only by a command from the computer. After the message is received by the microcontroller, this message is printed in LCD panel. Besides, the microcontroller produces a warning sound in order to inform the operator for the received message.

The program used in the main computer is coded under C++. The main task of the program is to observe the serial port continuously and to process the received data.

The outputs of all five sensors are in different scale. Because of the use of analog multiplexer, a hardware calibration can not be performed for each sensor. Therefore a software calibration technique is used and all outputs of the sensors are scaled into a same interval. The K_n parameter in (2) stands for the calibrated value of the n. sensor, whereas F_n stands for the uncalibrated value of the n. sensor.

$$K_n = (F_n - \min\{F_n\})\frac{\max\{F_n\}}{A} \qquad (2)$$

Besides, during the calibration process, when the hand is completely open, minimum value of F_n is obtained. This value is denoted by min $\{F_n\}$. On the other hand, when the hand is completely closed, maximum resistance value is obtained form the sensors and this is denoted by max $\{F_n\}$. Here, A stands for the theoretically maximum value that can be achieved from the sensors. Hence, all sensor data are mapped into the same universe by this calibration procedure.

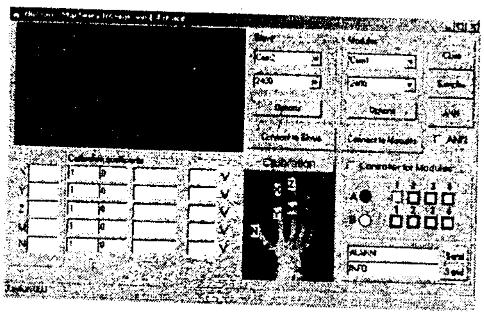

Figure 4. User friendly interface screen

The software presented here, can be used as an interface to control the other peripheral units as shown in Figure 5. In the current work, two peripheral units are controlled by the glove mechanism which includes four functions for each. By use of glove mechanism, each function can be controlled as an ON/OFF switch. Software Program first, transmits the address of the peripheral device, then transmits the code of the function and finally transmits the parameter of the function to the microcontroller.

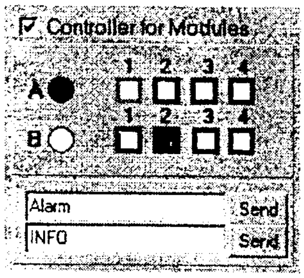

Figure 5. User friendly screen of control operation

Whenever the control is active, the program considers the motion of three fingers. Thumb is used for transition between the peripheral units. Each closing and opening of the thumb causes a transition from one peripheral unit to the other. Besides, each opening and closing of the index finger brings out transition from one function to the other. Finally, each opening and closing of the mid finger designates the function parameter and causes a transmission of command to the peripheral units. Throughout the process, the operator or the user can be able to follow the process by the user friendly screen shown in Figure 5. Also, in order that the user may work independently, all the operations are sent to the glove as an information message. In this way, the user can be free from doubt that all the commands are perceived correctly by the computer.

6. The analysis of sensor data via ANN

In this work, in order to find the angles which are spanned by the hand joints, an ANN is used. Because, there are five sensor for input and five for output, 5 input and output neurons are used. On the other hand 50 neurons are used in the hidden layer. As an activation function, tangent sigmoidal function is preferred because of its continuous structure. The tangent sigmoidal function which is shown in Figure 6 can take values between [-1, +1] as shown in Figure 6.

The analytical definition of the sigmoidal tangent function is as

$$\varphi(n) = \tanh(n) = \frac{2}{1+e^{-2n}} - 1 . \quad (3)$$

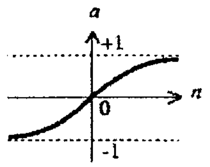

Figure 6. Hyperbolic tangent activation function

During the training phase of the ANN, Levenberg-Marquardt optimization method is used [9]. The necessary condition for the use of this method is that the activation function should be continuously differentiable, since the derivative of the function is used during the training phase.

During the training phase of the Multi layer perceptron (MLP), 40 normalized data are used which are mapped between [0, 1]. Because of the highly nonlinearity of the system, the amount of the data used in the training phase is very important.

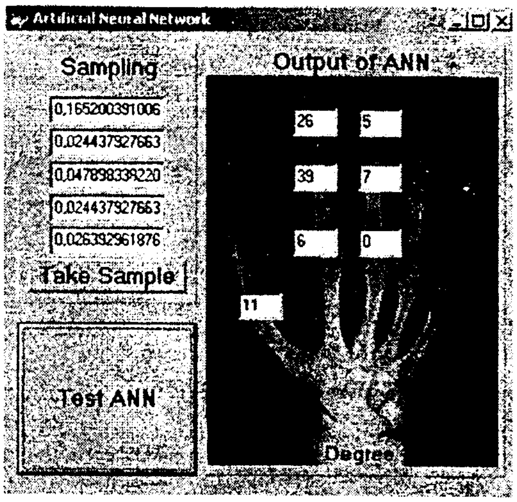

Figure 7. Screen shot of the ANN subsystem

Figure 7 shows a screen shot of the ANN system. Data captured from the ADC first mapped between [0,1] and then applied to ANN. The angular positions of the finger joints are then obtained by using the data taken from the output of the ANN.

7. Results and discussion

In this work, in order to fulfill the man – machine interaction, an electronic glove system is proposed. The angular position of the eight junction points of a human hand is measured by flex sensor mounted on a glove and transmitted to the computer where the data is analyzed by an ANN

The ordinary logic, which is used as implication of angular positions, could not be able to simulate the finger motions correctly because of the nonlinearities within the hand. However the ANN is less sensitive to noise errors generated by sensors. Thus, ANN is used in the implication of the angular motions. Besides, the ANN has the ability to tolerate the errors that may generated by the use of different users.

As an application, a control process is performed by the use of glove mechanism. Although this way of use can be used in industrial applications, it may also be useful for paralyzed people. By the help of the system powered by software, paralyzed person would be able to control any electronic device in her/his environment. For example: he/she would be able select the telephone by moving his/her thumb then select any number from the address book by moving index finger and finally may fulfill the call operation by moving mid finger.

The software designed for the target system is completely independent from the main system. The purpose of the main system is only to transmit the required information needed by the target system to fulfill operation. The rest of the work is all done by the target system. This type of design structure makes the system portable and adaptable.

The only drawback of the designed system is that it is not wireless. However the system can be easily modified my embedding a RF module to both sides. In this respect the system can be made independent from computer in a limited region.

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