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Fuzzy Logic Technique to Control a Robot Based on Non-Invasive Brain Computer Interface by Human Group

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***Abstract*— the main idea of this project is movement control of a robot based on non-invasive brain computer interface and with several human simultaneously thinking about choosing a direction of move. In these experiments we used three persons to control the robot. For example, when a car is to move on the road or street, suddenly the driver experiences drowsiness or apoplexy and then lose the car control, In this case with this method car controller uses brain activities of other persons in the car to control the car movement in short time. In this project, to access the most efficacy, we experiment two different methods, and extract brain activities in real-time for analysis and selection of the best direction of move.**

Keywords-component; Robotic, BCI, Intelligent Control, Soft Computing, Fuzzy control

I. INTRODUCTION

HE Brain Computer Interface (BCI) is technique to convert human thoughts to suitable and understandable command for machine, robot or any actuator, one of the most common methods to get brain activity signals is electroencephalography (EEG) system which is easier to use, non-invasive and also low cost method in compare to other brain computer interface systems [1], [2]. In Recent researches of non-invasive brain computer interface based on EEG technique to control actuators result of create some equipment that controlled with brain, for example electrical wheelchairs [3], mobile Robots [4], humanoid robots [5].

In all the researches and projects so far have been done with these methods (Brain computer interface), all subject controlled by one person, an example of these researches that has been done by Millan et al. [4] was on mobile robots has been controlled by a person thoughts. Or control the electrical wheelchair made by non-invasive method with thinking about it that the person was able to move between several and different rooms [3]. Or in another non-invasive BCI project a person was able to control the humanoid robot movement in left, right and forward directions with think about the direction of move [5]. In all of these researches, one person control the one subject by mental, So far the experiment has not been

done by several person to control an one subject such

As control of robot movement for example control movements of a humanoid robot by several person or in a Sensitive motion control of a robotic arm, for example, working with chemicals materials and other materials that are dangerous For humans by a few specialists or the control of a surgeon robot by thinking of the several surgeon to surgery a patient. But to this research we apply new methods to control a robot based on non-invasive brain computer interface with three people they think about robot movement and we apply absolute fuzzy rules to get better and high accurate results.

II. METHODS

A. Training Protocol

In the first step, directions of move were asked of persons that participated in these experiments to thinking about the (Left, Right and front) movement direction, and then we get the brain activity signals for training the controller system to get selected movement directions.

B. Experimental setup

EEG electrodes position according to the international 10-20 standard is shown in fig.1 in this figure the nine electrodes (FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4) are used as main channels. All of these nine electrodes are referenced with the right and left brain mastoids [6].

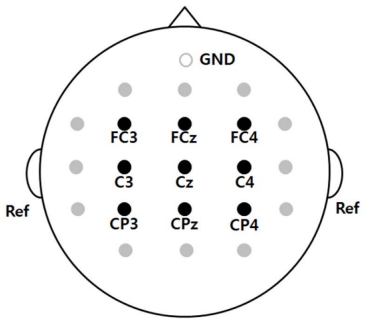

Figure1. EEG electrodes position according to the international 10-20 Standard. [6]

C. Data Acquisition

We use of three person with health condition without any disabilities (age between 20-30 years old) in our experiments, they were thinking about three directions (left, right, forward) recording brain's activities signals

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from electrodes placed on C3, C4, Cpz positions and brain activities result of one of them shown in fig. 2.
In this figure, when a person thinks about one of each directions the brain activities increased more than the Normal conditions. In 3D image, the brain activity is shown when person thinks about right direction sampled from C3 electrode channel, in image hot color shows high brain activities and cold color shows low brain activities.

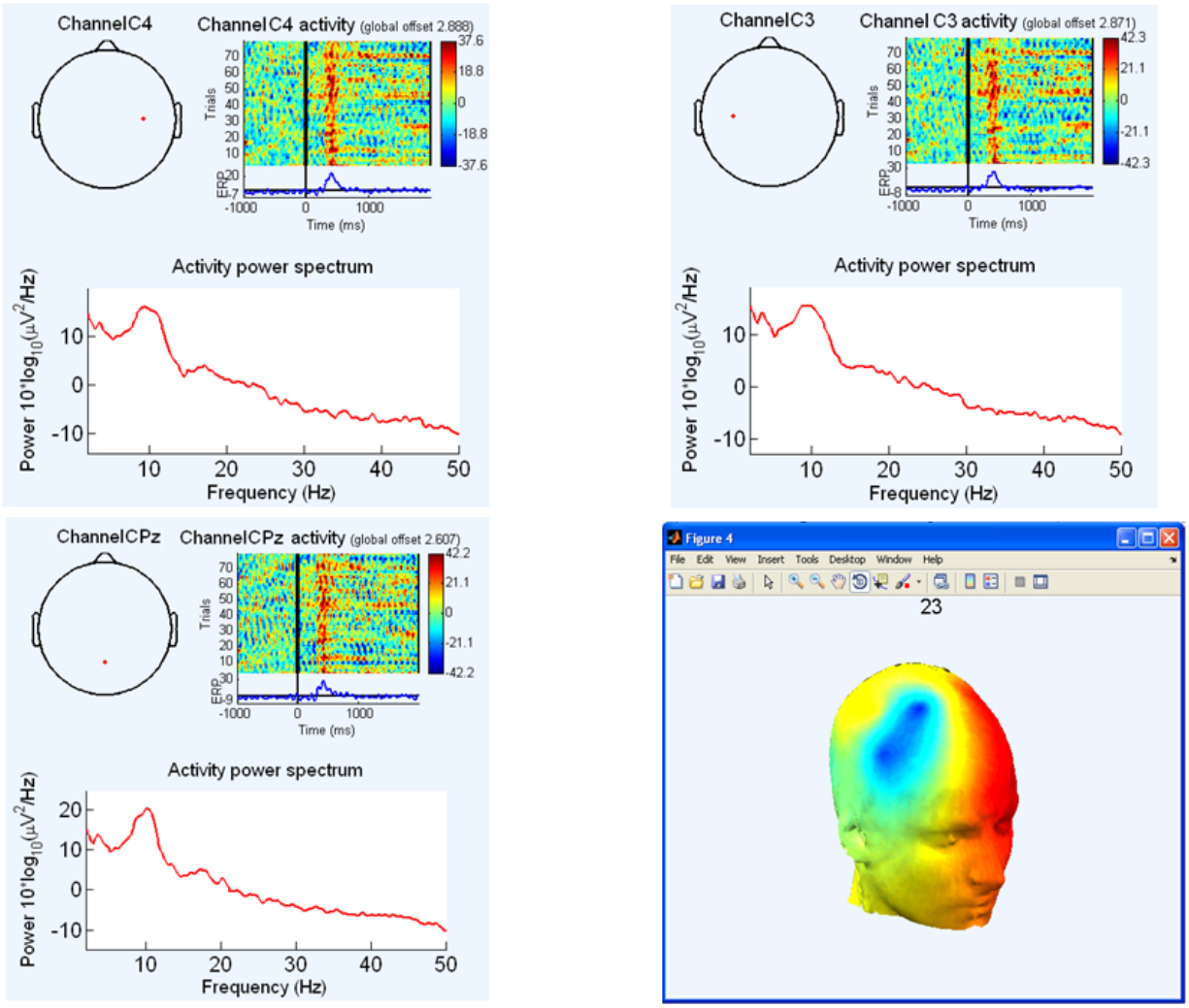

Figure2. Brain activities in C3, C4, and Cpz electrodes position and 3D image of brain activity when person choose right direction, red color shown high activity, and cold color shown low activity

C. *Feature Selection*

The EEG signals divide in several groups the main difference of this grouping determinate by frequency range. Delta rhythms are specifying the deep sleep action and have high level amplitude in 0Hz to 4Hz frequency range. Theta rhythm occurs in 4Hz to 8 Hz frequency range in the drowsiness, idling or meditation state. Alpha rhythm occurs during reflecting or relaxing with 8Hz to 14 Hz frequency range. By closing the eyes we can extract alpha rhythms on the scalp. Beta rhythms occur in 13Hz to 30 Hz frequency range and when user has activity or centralization on a subject these rhythms appear on the scalp. Gamma rhythms occur in frequency range between 30Hz to 100Hz and during the listening or visual states These rhythms appear on the scalp of user. And mu rhythms occur in frequency range 8Hz to 13Hz while the user imaging about movement or move their body in actually for example moves hands or legs.

D. *Data analysis*

Main idea of this experiment is the sampling of brain activity from three C3, C4, and CPz electrodes channel of person's brain. And compare them together to choose correct direction.
When two or more than one person selects same direction

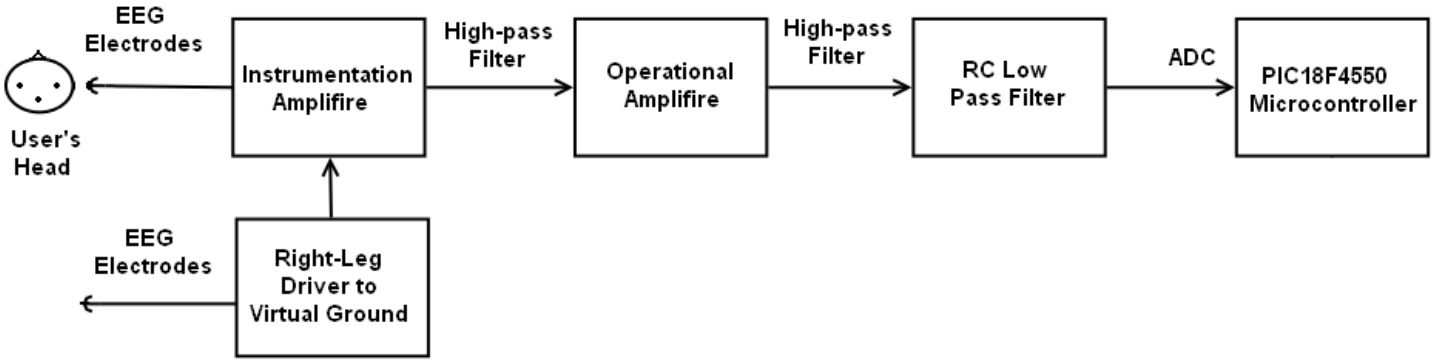

Figure3. Block diagram of hardware to obtain brain activities to microcontroller for analysis signals

This direction is chosen as a correct direction. For Example, when persons A and C select the right direction and person B selects left direction, controller issues right command to robot. To get electrodes signal and amplify it to apprehensible signal, we use the circuit schematic that blocks diagram provides in fig. 3.

III. CONTROL SYSTEM

A. *Main Controller*

For analysis of the amplified brain activities and movement control of robot, we need a controller that has some ability to converting several analog signals to digital for analysis and processing.

In these our experiments, we use of the PIC18F4550 microcontroller, produce by Microchip Corporation which has some powerful abilities such as processing speed up to 12 Mb/s. and 10-bit, up to 13-channel Analog-to-Digital converter module (A/D) with programmable acquisition time [7]. These abilities help us to do these experiments.

B. *Sampling and amplifier circuit*

We use of an amplifier circuit with a total gain with 1500. In the first stage of this amplifier we use of an instrumentation amplifier circuit with AD620 op-amp and differential mode to increase noise immunity. The gain of this stage is about 23. To provide virtual ground for instrumentation amplifier a CA3140 operational amplifier that uses as buffer that provide a 2.5v with two resistor R5 and R6 voltage divider circuit. In the next stage of this circuit uses of RC HPF (high-pass filter) circuit to deletion very low frequency signals, the Cut-off frequency of this high pass filter is approximately 0.13 Hz.

In the next stage, the signal applies to the second stage amplifier. This stage with 3140 operational amplifier provides voltage gains about 60. At the next signals cross over RC LPF (low-pass filter) with a Cut-off frequency about 50Hz, the main reason of choose this filter was for reduce and deletion of 50Hz or 60Hz power lines noise, while removing 50-60 Hz power line noise from the signal. With this circuit we are able to amplify the signals with

120µvpp. the circuit diagram schematic of this EEG amplifier shown in fig. 4.

C. *Electrodes position*

In these experiments, we placed three electrodes on scalp of each three persons who participate in the experiments. And use same electrode position for all.
The electrodes positions are shown in fig.5 that shows person's brain from top view named with E1... E9.

Also we can use right leg or ears persons to connect reference of sampling and amplifier circuit.

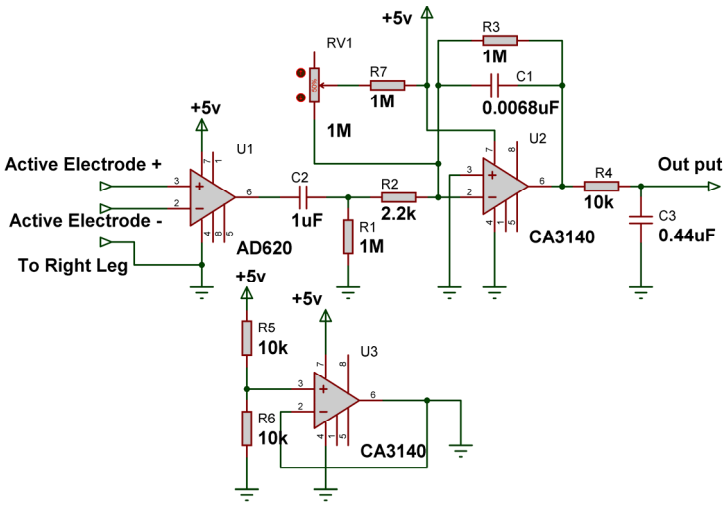

Figure4. Amplification circuit to amplify an individual electrode signal of brain activities

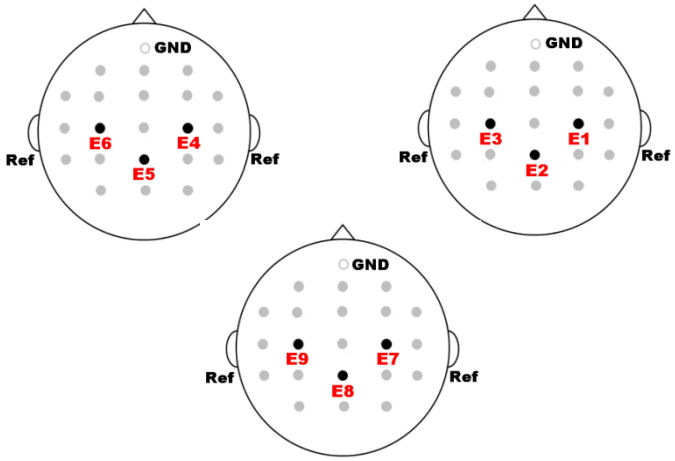

Figure5. Electrodes position on three person scalp that named with E1 to E9, reference signal connect to ear, also connect gnd of sampling and amplifier circuit to electrode position that named with GND on scalp.

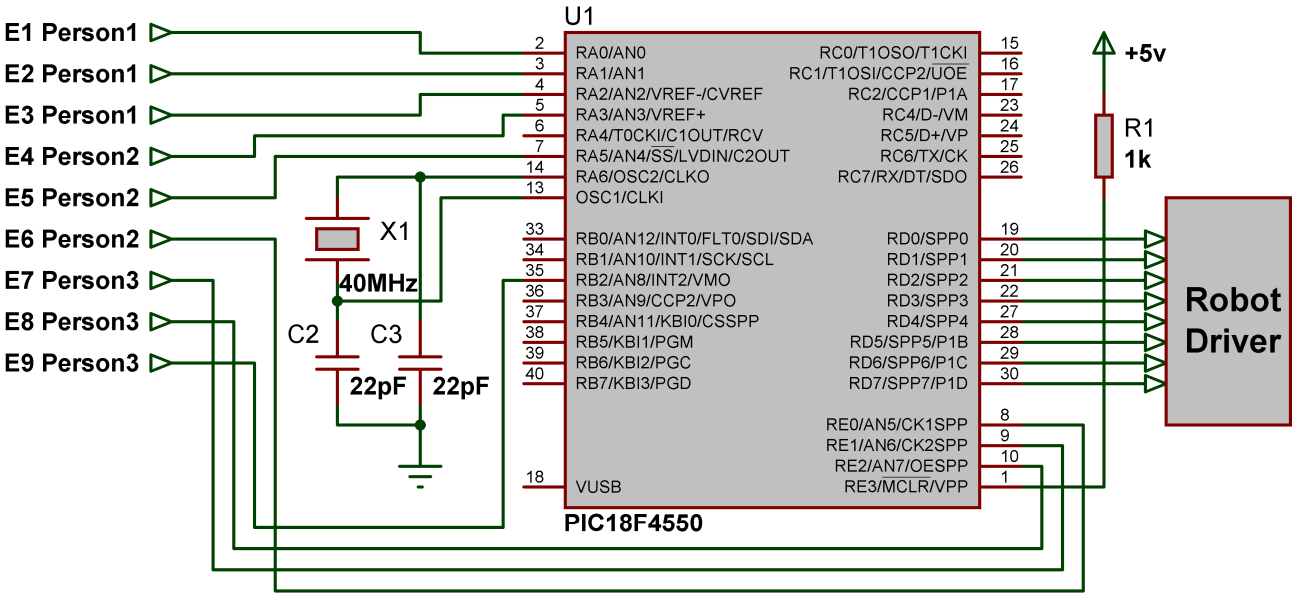

Figure6. Microcontroller circuit schematic for converting analog electrodes signal to digital and analysis and control the movement of robot

D. Controller circuit for the first experiment

To convert the analog signals of sampling and amplifier circuit, we apply the circuit schematic is shown in fig.6.

To this figure, we connect all nine electrodes signal to ADC (Analog to Digital Converter) inputs of microcontroller, and after converting these signals with 10bit resolution of Microcontroller ADC inputs we can analyze data and transmit proportionate directions data to target robot. As we connect all nine electrode signals to microcontroller, Also converting of analog to digital signals always takes time and is a time-consuming process; this method has slow response than we want.

D. *Fuzzy logic rules to get directions*

To define all states of electrodes signals and analysis of these signals, we use of these fuzzy rules that define all states provides in table II table III and table IV. In these tables outputs mark with blue color are active electrodes. All of these rules implement with c language in microcontroller.

E. Controller circuit for second experiment

In this experiment we use of adder circuit with inverter buffer to add same electrodes signal of same position on scalp, For example we add E1, E4 and E7 (these electrodes are placed on right position of three persons scalp) electrode signals together with a single AD620 op-amp chip and because adder result has inverted with 180 degree we need to invert signal with inverter circuit with another AD620 op-amp as shown in fig.7.

In fig.7, U1, U2 and U3 are adder op-amps, and add three electrodes signal and U4, U5 and U6 are inverter buffer op-amps that amplify the output signals of adder op-amp and invert the signals with 180 degree to send positive signal to ADC inputs of microcontroller. With this technique, we increase the speed of analysis of the signals through reducing the ADC inputs, and analog to digital Converting operations, to three times faster response. When more than one person chooses each of the three

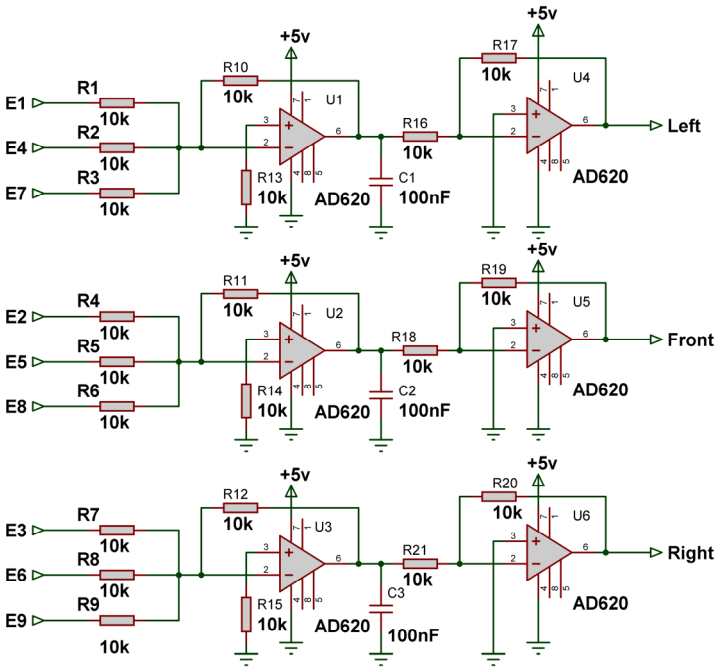

Figure7. Adder and inverter buffer circuit schematic to add same position electrode together

signal level on output reaches to higher compared to other outputs, For example, assume that the two persons choose left direction and one of them chooses right direction in this case, E1, E4 electrodes placed on scalp, have high ERP's (Electrical Related Potential) level and E9 electrode have low level ERP's, as result, the left output have higher potential than the other output and microcontroller after convert this signal to digital, analysis these data with predefined algorithm and choose the best direction and send proportional signals to robot driver to apply direction for robot movement.

TABLE I
FUZZY RULES TABLE PART I

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Person1(A)	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1
Person2(B)	E4	E4	E4	E5	E5	E5	E6	E6	E6	N.S	E4	E5	E6	N.S	N.S	N.S
Person3(C)	E7	E8	E9	E7	E8	E9	E7	E8	E9	N.S	N.S	N.S	N.S	E7	E8	E9
Left	On	On	On	On	Off	Off	On	Off	Off	Off	On	Off	Off	On	Off	Off
Front	Off	Off	Off	Off	On	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Right	Off	Off	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	Off	Off	Off	Off

TABLE II
FUZZY RULES TABLE PART II

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Person1(A)	E2	E2	E2	E2	E2	E2	E2	E2	E2	E2	E2	E2	E2	E2	E2	E2
Person2(B)	E4	E4	E4	E5	E5	E5	E6	E6	E6	N.S	E4	E5	E6	N.S	N.S	N.S
Person3(C)	E7	E8	E9	E7	E8	E9	E7	E8	E9	N.S	N.S	N.S	N.S	E7	E8	E9
Left	On	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Front	Off	Off	Off	Off	On	Off	Off	On	Off	Off	Off	On	Off	Off	On	Off
Right	Off	Off	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	Off	Off	Off	Off

TABLE III
FUZZY RULES TABLE PART III

	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Person1(A)	E3	E3	E3	E3	E3	E3	E3	E3	E3	E3	E3	E3	E3	E3	E3	E3
Person2(B)	E4	E4	E4	E5	E5	E5	E6	E6	E6	N.S	E4	E5	E6	N.S	N.S	N.S
Person3(C)	E7	E8	E9	E7	E8	E9	E7	E8	E9	N.S	N.S	N.S	N.S	E7	E8	E9
Left	On	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Front	Off	Off	Off	Off	On	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Right	Off	Off	On	Off	Off	On	On	On	On	Off	Off	Off	On	Off	Off	On

To get the direction according with three output of adder circuit we use of this algorithm and to experiment accuracy of the algorithm we write it in C programming language for
Microcontroller and produce suitable output for robot driver to control robot movement.
Fig. 8 showed the microcontroller circuit schematic with three ADC inputs of adder circuit.

If (Left > Front) and (Left > Right) then Left

If (Front > Left) and (Front > Right) then Front

If (Right > Left) and (Right > Front) then Right

IV. RESULTS

As described earlier, with two experiments the speed of output response reaches three times faster and the accuracy of this controller to choose the correct direction between three subject with nine electrodes with fuzzy logic implementation reaches higher and accurate

response because all states of these nine electrodes signal are defined as shown in three tables (II, III and IV) above.

The hit ratio and response time of the second experiment provide in table IV, three subjects A, B and C that participated in this experiment, we get the hit ratio of subject a reach to 77.16% and for Subject B up to 88.96% and 82.1% for subject C.

TABLE IV
THE RESULT OF THE SYSTEM'S PERFORMANCE

		Person1 (A)	Person2 (B)	Person3 (C)
Hit ratio (%)	Left	70.5	85.8	84.2
	Front	78.3	89.1	68.7
	Right	82.7	92	93.4
	Ave.	77.16	88.96	82.1
Response Time (Sec.)	Left	2.62	3.61	2.16
	Front	3.12	2.89	2.97
	Right	2.28	3.58	3.46
	Ave.	2.67	3.36	2.86

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