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Solve the Rubik's Cube with Robot Based on Non-Invasive Brain Computer Interface

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Abstract — **Main purpose of this project is to solve the Rubik's cube with a robot based on non-invasive brain-computer interface without using hands and only thinking about the rubik's cube rotation. This method improves speed of solving and also helps disabled persons who they can't solve the Rubik's cube with their hands.**
To this new idea we use Emotiv EPOC Neuroheadset to extract the brain activity signals and use LEGO Mindstorms NXT 2.0 robot as target to control and LabVIEW software to create functions and programs for analysis on extracted brain EEG signals to control target robot.

Keywords-component; Robot, Rubik Cube, Intelligent Control, Artifitial Intelligent, Brain Computer Interface

I. INTRODUCTION

The Rubik Cube is a amazing 3D mechanical puzzle that was invented in 1974[1] by two person, Erno Rubik, he was architecture professor and a sculptor from Hungary and they choose the name "Magic Cube" for inventions [2]. Classic Rubik's Cube has six faces and has nine pieces on each faces, each one of the faces has six fixed and different colors. (Red, white, orange, blue, yellow and green where blue is opposite green, and yellow is opposite white and red is opposite orange, and the red, blue color and white color are arranged in a clockwise direction) [3].

The (3×3×3) classic rubik's cube has twelve edges and also has eight corners. To arrange the cube corners there are 8! State or 40320 state. To arrange the all edges in rubik's cube there are 12!/2 or 239500800 possible states. And also eleven edges independently can be flipped, with the flip of twelfth edges of the rubik's cube that depend to the precede ones, that give 2^{11} or 2048 possible state. [4]

$$8! \times 3^7 \times (12!/2) \times 2^{11} = 43,252,003,274,489,856,000$$

There is about forty-three quintillion [5].
The main idea is solving the rubik's cube with brain computer interface with robot.

Brain Computer Interface (BCI) systems are methods to translate and convert the brain activities signals into the actual commands. Brain activities signals appear in some states such as electrical activity that measure by electroencephalography systems (EEG) this method has most commonly in Brain Computer interface systems because is non-invasive method to get brain activities and it is easier to use and also low cost to compare with the other methods such as EMG (electromyography) and fMRI (Functional magnetic resonance imaging) methods [6], [7].

These systems was able to control mobile robot that done by Millan et al. [8]. To one of these researches, human moved a robot between rooms based on non-invasive brain computer interface method successfully. And also navigating the Electrical wheelchair was another amazing subject of the non-invasive brain computer interface systems [8], [9].

Recently, many different applications of non-invasive BCI systems are used in researches and commercial etc., for example P300-based brain computer interface systems apply to control the movements of mouse cursor in the personal computer [10], or neural-prosthetics for spinal cord lesions patients [11], and also computer control spelling to write some word or letter with the mental task [12].

II. METHODS

The complete description of this project is shown in figure1 and we use Emotiv EPOC neuroheadset to get brainwave activities signals, in the first step we send these signals to Emotiv EPOC control panel software that provided by Emotiv company via wireless connection and default IP address set to local IP: 127.0.0.1 and Port:1726, set to Emocomposer software. After receiving brainwaves, we use program provided by Emotiv toolkit on LabVIEW to detect commands which is emitted from person's brain, and we send this command to Lego mindstorms nxt2.0 toolkit to issue related command with person's brain to target robot. Communication between computer and target robot was provided via Bluetooth connection.

A. Extract the Brain Activity Signals

First, we extract the brain activities with non-invasive method. To this project, we use Emotiv EPOC Neuroheadset from Emotiv Company. Emotiv Company was established in 2003 by four managing directors and scientists: miss. Tan Le,

Figure 1. Overview of the project with wireless connections between computer and headset and robot

She is entrepreneur in field of the technology and Nam Do from EPOC, and Allan Snyder, he was neuroscientist professor and Neil Weste, and he was chip designer.

This neuroheadset has fourteen electrodes and two references for most accurate and resolution and with the Hi performance wireless communication user's get many range of motions, this neuroheadset has Lithium Battery that provides Twelve hours for continuous use, it also has a two-axis gyroscope for measuring head rotations. These specifications provide ability to use this non-invasive EEG Neuroheadset in our experiments.

EEG electrodes positions of Emotiv EPOC neuroheadset with respect to the international 10-20 System are shown in figure 2.

The Emotiv EPOC Neuroheadset technical specifications are listed in table 1.

Also, for training brain wave to get related command, we use of Emotiv Control Panel from Emotiv Company. This software creates a connection with Emotiv EPOC Neuroheadset via wifi. To these experiments, we train software to issue related commands that are chosen by persons.

For example when person chooses the rotate right direction in his brain, we train software for this command. This requires that we train software for all commands such as Natural state, Right, Left directions, and also Pull, Lift and Drop.

B. Signals Analysis

To get brainwaves via wireless connection, we use "Emotiv EPOC Control panel" and send it to LabVIEW software for analysis on brain activities signals with functions and programs that are provided in LabVIEW software. LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a system design platform and development environment for a visual programming language from National Instruments Company [13]. Main purpose of using this software to programming was about some point in this software such as graphical programming with prepared blocks and functions and some useful toolkits to working with target robot and EEG neuroheadset.

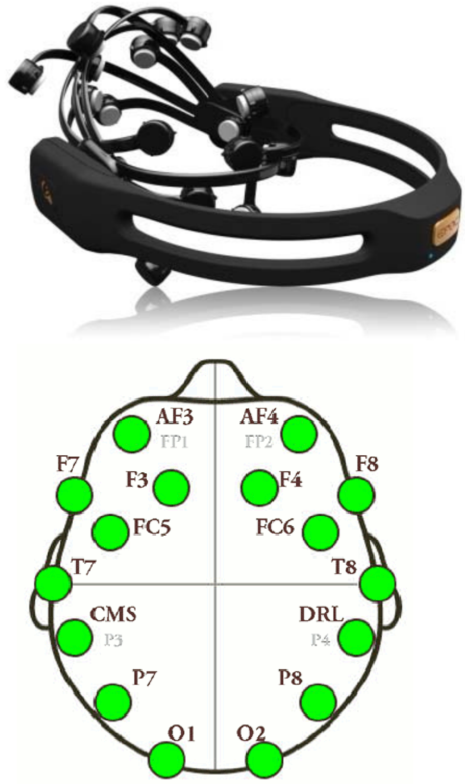

Figure 2. Emotiv EPOC Neuroheadset Electrodes position on brain respect to the international 10-20 System [14]

To these experiments, we use "Cognitiv Suite" commands to control the arm of target robot and related command to rotate rubik's cube. For example, when a person thinks about drop action, arm of the robot drops on rubik's cube and is ready for the next action, and when the person thinks about the lift command, robot arm is placed on the top of the rubik's cube. For rotation of rubik's cube to left, we issue left command with Emotiv neuroheadset and for rotation to right, we must issue right command. Right and left commands are applied to robot tray. To move back face of rubik's cube to tray position, user should issue pull command with robot arm. To analyse and detect direction that is chosen by user, we use LabVIEW Emotiv Toolkit.

TABLE I. EMOTIV EPOC NEUROHEADSET SPECIFICATIONS [15]

Number of channels	14 (plus CMS/DRL references, P3/P4 locations)
Channel names (International 10-20 locations)	AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4
Sampling method	Sequential sampling. Single ADC
Sampling rate	128 SPS (2048 Hz internal)
Resolution	14 bits 1 LSB = 0.51μV (16 bit ADC, 2 bits instrumental noise floor discarded)
Bandwidth	0.2 - 45Hz, digital notch filters at 50Hz and 60Hz
Filtering	Built in digital 5th order Sinc filter
Dynamic range (input referred)	8400μV (pp)
Coupling mode	AC coupled
Connectivity	Proprietary wireless, 2.4GHz band
Power	LiPoly
Battery life (typical)	12 hours
Impedance Measurement	Real-time contact quality using patented system

Figure 3 shows the program to read direction that is selected by user. This program receives EEG signals of Emotiv EPOC Control panel and edk.dll.

C. Robot Controling

The target robot which is used to rotate the rubik's cube in all directions is "LEGO Mindstorms NXT 2.0" from LEGO Corporation. Lego Mindstorms NXT 2.0 is the second version from LEGO's Mindstorms series, launched on August 5, 2009 at the Lego Shop in the U.S. This controller has some abilities such as 32-bit Atmel AT91SAM7S256 main microcontroller (256 KB flash memory, 64 KB RAM), 8-bit Atmel ATmega48 microcontroller at 4 MHz (4 KB flash memory, 512 Bytes RAM) and four 6-pin input ports (ports 1-4), three 6-pin output ports (ports A-C) and Bluetooth Class II V2.0 and USB Port and some sensors such as Color Sensor, Light Sensor, Ultrasonic Sensor, etc. and some other specifications that provide some abilities to make robot to rotate the rubik's cube in all directions.

To control robot for rotation of the rubik's cube, we use LabVIEW toolkit for LEGO Mindstorms NXT, and program to control two motors of robot to rotate rubik's cube in all directions as shown in figure 4.

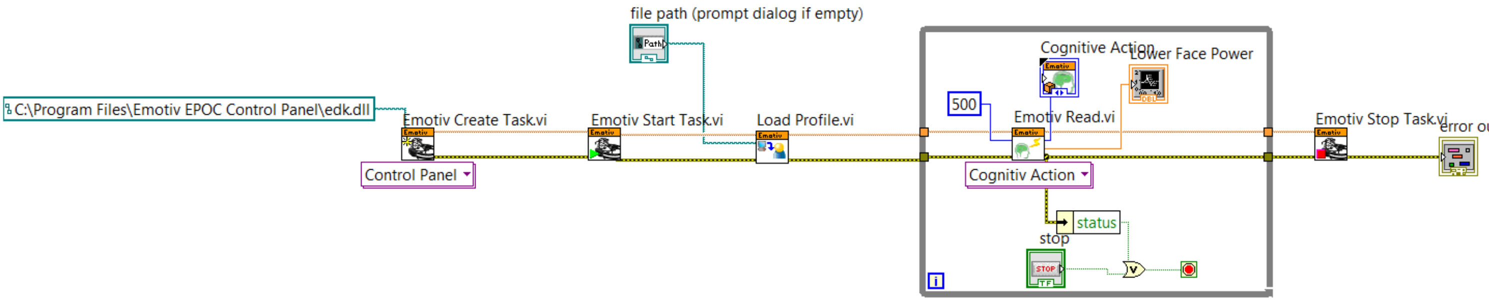

Figure 3. LabVIEW program to read directions by Emotiv EPOC Neuroheadset

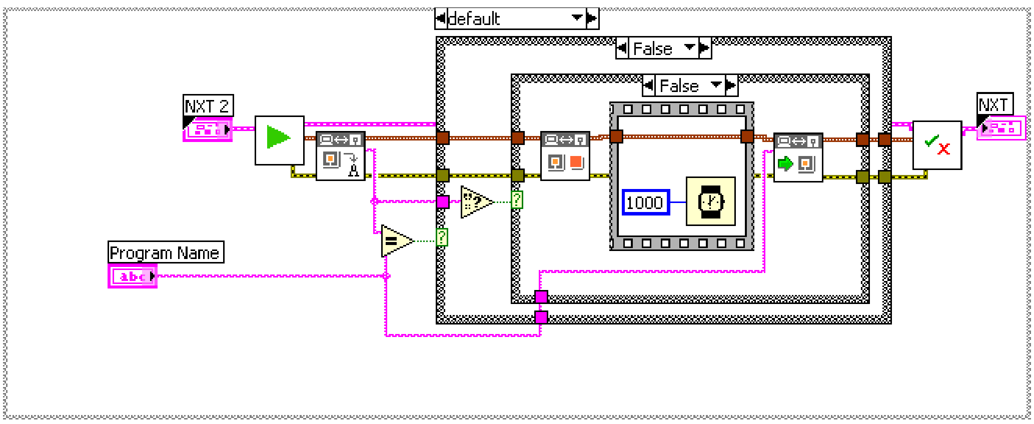

Figure 4. program to control LEGO Mindstorms NXT 2.0 with LabVIEW toolkit

The robot has two motors, one for moving arm to lift, drop and pull rubik's cube and also the other is used to rotate the robot's tray. Figure 5 shows the movement of robot that executes pull command and also this picture shows rotation direction of tray with red arrow on the picture. When the person thinks about drop command after detecting this command with Emotiv control panel, this command is issued to LabVIEW and after process on these signals, LabVIEW sends related command to arm's motor to rotate left with suitable degree to do drop command. And the same steps for lift command also apply.

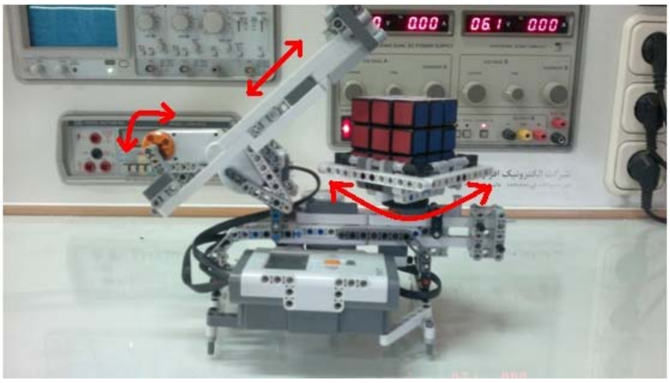

Figure 5. Direction of tray rotate and arm, and rotation motor's Arm

For rotation of any row of rubik's cube, robot arm drops on rubik's cube and stays at this state to hold the rubik's cube and then we apply left rotation command to rotate robot tray to left. The steps are shown in figure 6. As seen in this figure, person issues left command to sort the red row with upper rows. To change the face of rubik's cube, person issues pull command with mental task and arm of robot pulls the Rubik's cube and prepares for robot's tray. This action is shown in figure 7.

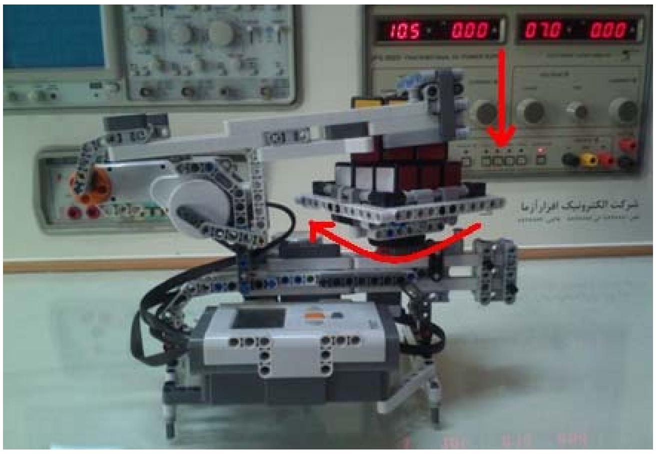

Figure 6. issue drop command to arm and rotate to left command to tray

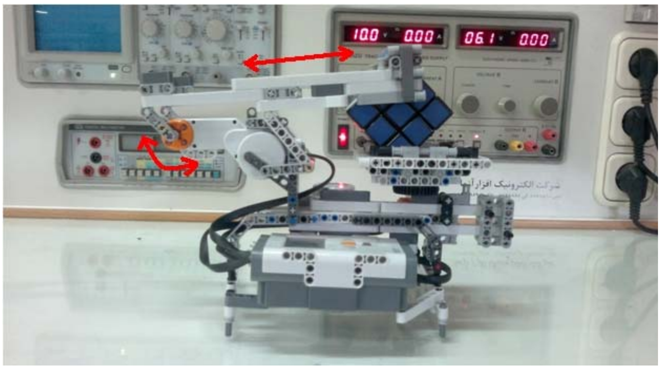

Figure 7. issue pulls command to arm for changing face with the fix tray

III. RESULTS

During the experiments of project for the first time we use a normal person without any disabilities .and without very good skill to solve the rubik's cube; we only use this person to test the movement robot to rotate the rubik's cube in chosen directions by person's brain. The results were favorite. Because more commands are chosen by this person for rotation of rubik's cube in left and right by fixed tray that controlled with a motor on port of robot, we had some problems to control robot arm when the person chose the push and pull command for the arm and drop and lift command with EPOC headset.

In the second experiment, we used another person with the same conditions with the first person but he had very good skills to solve rubik's cube. Results were our favorite about this person but same problems to push and pull and lift and drop was occurred for this person.

Results of the experiments are described in table 2. As described in table, six commands are issued by two persons on experiments "rotate left and right", and "drop and lift the robot arm", and "push and pull robot arm". For example, 86.6% success for person1 to choose "rotate left" and 80% for person 2 are considered .Also, there is 66.6% hit ratio for person1 to choose "rotate right" and 93.3% for person2.

But these hit ratios about the moving arm were not very well. For example, we get 60% hit ratio for person1 to choose "pull arm" command and 40% for person2. Hit ratio on "lift arm" command for person1 was 50% and for person2 70%. And final hit ratio on "Drop arm" command for person1 was 40% and for person2 was 30%.

TABLE .II RESULT OF ISSUE COMMAND BY PERSONS

		Person1 beginner	Person2 professional
Hit ratio	Rotate Left	13 out of 15	12 out of 15
	Rotate Right	10 out of 15	14 out of 15
	Pull robot arm	6 out of 10	4 out of 10
	Lift robot arm	5 out of 10	7 out of 10
	Drop robot arm	4 out of 10	3 out of 10

IV. CONCLUSION

Although our experiment was somewhat successful, during these tests, but participated persons had some exercises on rotation of rubik's cube with robot before. To get skill with this system and to solve rubik's cube, user should spend time to get dominating with this headset and robot.

These new ideas help disabled persons and some other persons who want to learn working to solve rubik's cube without hands and only with mental task.

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