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Twenty-Fifth Anniversary of the First EOG Controlled Robot

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Introduction

Controlling robots using signals from a human head started in 1988 with control of a robot using EEG signals [1-3]. The next year, 1989, the first control of a robot using EOG signal took place [4,5]. This Editorial marks 25th Anniversary of that event. In the sequel, before describing the 1989 pioneering event, the paper will describe the challenge of controlling objects using biosignals, stated by Vidal [6]. The 1989 event described here is a relevant milestone for Computer Science and Systems Biology in the area of biosignal pattern recognition and biosignal driven control.

Vidal's Challenge, 1973

In 1973 Vidal [6] stated the challenge of moving objects using biosignals. In the challenge, besides spontaneous EEG, he mentions evoked potentials, EOG, EMG, GSR, and ECG. For him of special interest in the challenge are CNV potentials. Here is the quote of his challenge:

"The Brain Computer Interface system is geared to the use of both the spontaneous EEG and the specific evoked responses triggered by time-dependent (visual) sensory stimulation under various conditions. In addition, other biosignals that are of interest for interfacing the physiological man and the machine are to be included later in the project. Eye movements, muscle potentials, galvanic skin reflex, and heart rate are ready examples which hold promise for particular applications. Acoustic and somato-sensory evoked responses also need to be evaluated since the latter, in particular, affords less variability than the visual evoked responses. Of special interest also is the contingent negative variation (CNV), a slow negative baseline shift of the EEG signal that relates to expectation, attention, and arousal."

Vidal himself was the first one responding to his challenge and in 1977 he achieved the first EEG control of a graphical, computer screen object [7]. In 1988 the first physical object (a robot) was controlled using EEG signals [1]. The event pointed out an engineering approach of the long lasting problem of psychokinesis. In 1989 the EOG part of Vidal's Challenge was achieved with first EOG control of a physical object, a robot.

Experimental Setup

The experimental setup of the system for an EOG (and EEG) driven robot control [4,5] is shown in Figure 1.

The experimental setup consists of:

1. A human subject encoding commands in the biosignals. For EOG the movement of the eyes can be in direct relations with movement of the robot. Or, a movement of the eyes can trigger a more complex pre-programmed robot behaviour, for example avoid obstacle behaviour.

2. An interface toward a computer, a device which captures those signals, which with today's technology can be wireless

3. A computer based processing of EOG signals, including learning and pattern recognition algorithms,

4. An interface toward the physical object (e.g. robot), which with today's technology can be wireless

5. A feedback (visual, audio, etc.), ensuring that the subject who controls the physical object observes results of her/his intentions which were encoded in EOG patterns.

The 1989 Experiment

The experiment of EOG driven robot control was carried out in the Laboratory of Intelligent Machines, Bio-information Systems, and Systems Software (LIMBISS) at the Electrical Engineering Department at Cyril and Methodius University in Skopje, Macedonia. As part of a funded project named Adaptive Industrial Robots, a Robot Polygon was built for experiments with several mobile and manipulative robots. It was a rather cubical metal rack with two floors. On the first floor it was a table with size similar to a ping-pong table. The second floor of the rack carried a movable platform with wheels using the metal rack as rails. The movable platform contained robots controller (in a standard industrial 19" rack element) and cameras. The purpose of building the Robot Polygon was to solve cabling problems between a control computer and several robots controlled on the table. The control computer outside Robot Polygon, at that time a IBM PC, was connected to the robots controller on the second rack floor, which had cables to each robot below on the first floor of Robot Polygon. With cables coming from above the mobile (and manipulative) robots were able to move and interact on the first floor table of Robot Polygon.

The human subject was sitting in a chair next to Robot Polygon and observing the robot s/he was controlling with EOG signals. A 19"
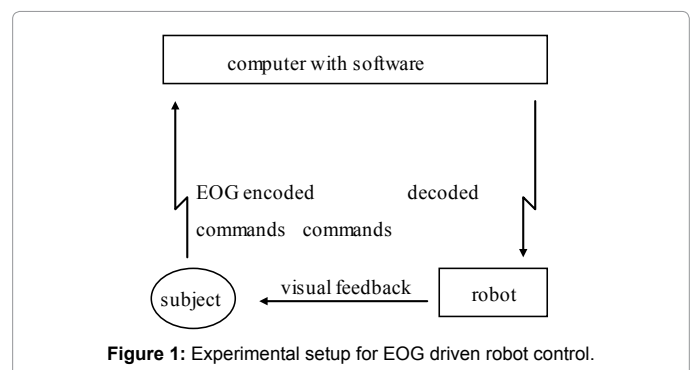

Figure 1: Experimental setup for EOG driven robot control.

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rack-based bio-potential amplifier was designed for the needs of the Laboratory and was made by company LME from Zagreb, Croatia. The bio potential amplifier pre-processed and transmitted the EOG signal from the subject to a 14-bits AD/DA converter purchased in Munich, Germany, which was placed inside the IBM PC. The robot named Adriel-1 was built out of a toy car with tactile sensors for sensing obstacles. The robot had a "coat" to have a look of a load carrier transport robot in a Flexible Manufacturing Systems (FMS) scenario, which was part of activities of the mentioned Adaptive Industrial Robots project.

The task of the human subject was to move the robot between two predefined spots on the table avoiding obstacles along the way. The eyes movements were "left", "right", "up", "down", and fast "blink" movement. The corresponding robot behaviors were "turn left", "turn right", "move forward", "move back", and "stop". The pre-programmed robot behaviors were only timer lengths assigned to particular movement. The "move forward" and "move back" behaviors have been assigned longer time periods; the "turn" behaviors have been assigned time just to turn the wheels.

The 1989 EOG Signal Acquisition for Robot Control

The standard way of collecting EOG signals today is shown in Figure 2. One electrode captures horizontal movement of both eyes and one electrode captures vertical movement of one eye. Each (+, -) setup has in addition an third "ground" electrode not shown on the Figure 2, placed on the forehead.

The 1989 experiment was collecting signals from both eyes separately, with a common electrode. The electrode placement was used as shown in Figure 3. The neutral electrode is placed on the earlobe, not shown in Figure 3.

With electrode placement as shown in Figure 3, the signal recording is shown in Figure 4.

With the recording shown in Figure 4, the EOG signals obtained are shown in Figure 5. It shows EOG signals for forward/backward movement of the robot, with up/down movement of the eyes (above), left/right movement of the robot with corresponding eyes movement (middle), and stop the robot with closing/opening the eyes (below).

Note that Figure 5 is composed of three different computer screens. Below each pattern in Figure 5 is the recorded signal, and part of the signal which is underlined is shown zoomed in the screen. The top signal shows zoomed the entire recorded signal, but the middle one and the bottom one shows zoomed just a fraction of the recorded signal.

The 1989 Software for EOG Robot Control

The 1989 EOG robot control program contained both learning (calibration) and examination phase [5]. The examination phase was identical to the exploitation phase, and was activated after the examination phase shows that the EOG patterns are recognized with sufficient accuracy, in our case 80%. The time for training was 30 minutes in average. Ten students were engaged in experiments of EOG driven robot and all of them were able to control the robot. A demonstration of EOG robot control was shown on a national TV program.

Discussion

Interestingly, the 1989 paper [4,5] was the only response to the EOG part of the Vidal's Challenge [6] reported in 20th century. Twelve years
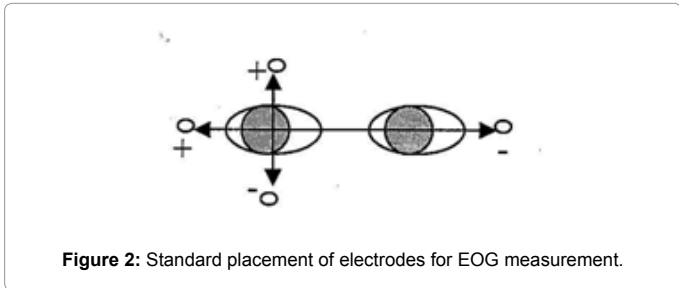

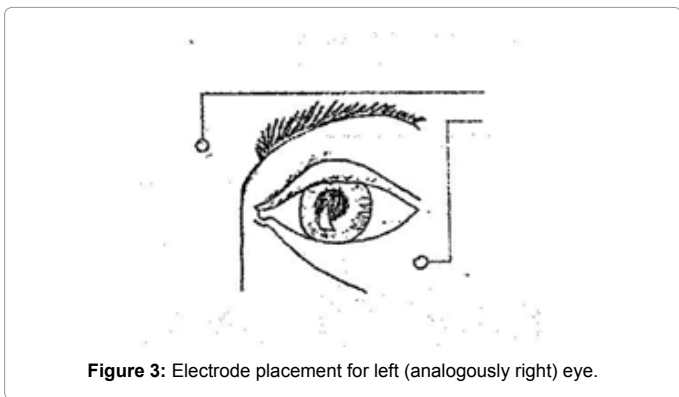**Figure 2:** Standard placement of electrodes for EOG measurement.

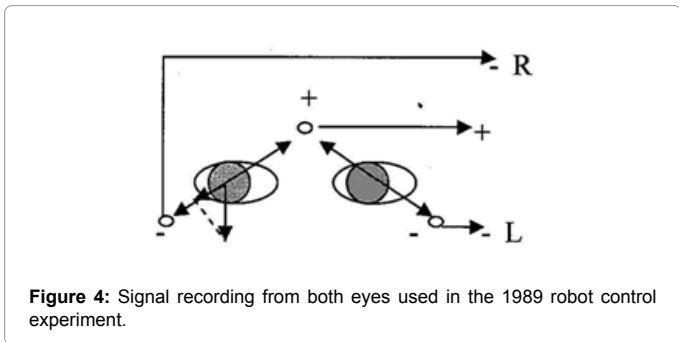**Figure 3:** Electrode placement for left (analogously right) eye.

Figure 4: Signal recording from both eyes used in the 1989 robot control experiment.
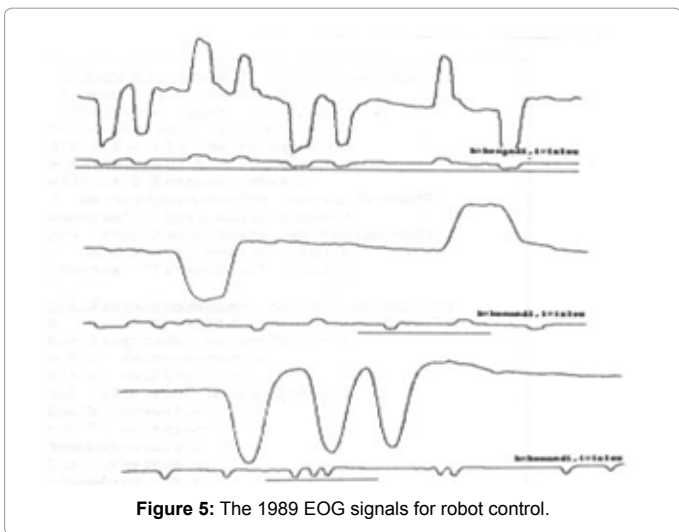

Figure 5: The 1989 EOG signals for robot control.

later, a 2001 paper [8] was the second paper dealing with EOG driven robot, toward further works on EOG driven objects (e.g. wheelchairs, robots) in the 21st century.

Conclusion

In 1989 a new direction in science and technology was opened: EOG driven control of robots. It can be viewed as response to the EOG part of the Vidal's Challenge (1973) for controlling objects using biosignals. In the process or resolving issues related to EOG driven control, a new method for EOG electrode placement was proposed and implemented.

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