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MOBILE ROBOT TRAJECTORY CONTROL: FROM FIXED RAILS TO DIRECT BIOELECTRIC CONTROL

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An effort in applying several methods of mobile robot control is briefly reported. The laboratory experience reported covers both bioelectric and non-bioelectric robot control. Only mentioning the non-bioelectric methods in a short review, this paper describes our biolectric robot control methods. Two trainable algorithms for bioelectric mobile robot control, using the EEG and EOG biosignals from the human head, are described.

Introduction

There are several communication channels between humans and robots, including tactile, speech, and visual, most commonly used in human communication. Direct bioelectric communication and control has not been widely reported in the robot control literature, although it becomes an interesing area of reasearch for systems control. [12]

Our effort concerns on bioelectric signals which could be obtained from the human head. Objective is to explore possibilities of communication between the human and artificial intelligence with "head to head communication". Parts of this task are contemporary widely explored as separate disciplines, like machine vision and spech communication, and are not of primary interest for this paper.

In the sequel we will describe, in short, our research in non-bioelectric mobile robot control. After that, we will give a more extensive description of the algorithms and exeperiments we have done in direct bioelectric mobile robot control.

Non-Bioelectric Mobile Robot Control

This part of the paper is actualy a message about a work in mobile robot control carried out at the University of Skopje. Starting 1982, in our laboratory we have investigated the following methods of mobile robot control:

Fixed rails

A robotized stacker crane storage was considered as a task. It is an industry application task and is installed in a local electric company stacker crane storage. A microprocessor based controller is mounted on a stacker crane, making a 3-degree of friedom mobile robot out of it. The trajectory is fixed, on rails. The inductive positioning sensors are mounted on the rails, and also on the robot. A PC controller supervises the work of two such robots, by a wireless signal transmissiton. The PC maintains also a data base for the situation in the storage. [7,8]

Drawn line

Experiments with a line follower robot are in the context of our biosignal control experiments which we are going to describe in the next chapter.

Tactile searching

A maze running experiments were carried out during 1982 and 1983. A toy car was adapted and armed with tactile sensors. The task was to follow a wall of a maze, and to sense a 5V source along the way; sensing it, the robot assumes a goal is reached, and stops. The software was written in the multitasking EDL language, and experiments were carried out on the Series/1 computer. The software was organized as pattern classification system, which recognizes situation and performs required action [1,3,7].

Distant control

A mobile platform was specialy designed to work as a distant controlled mobile robot. The control was done by a radio emiter and receiver. The work was done during 1986 [7]

Beacon referenced control

The beacon referenced control was the one on which we spent conceivable amount of time during 1983 and 1984. Out of a toy car we built a mobile robot which was able to follow a gradient light source. The sensors were photo resistors, able to sense a normal house bulb light. We believe that a beacon referenced control can be used as a principal method for control of a several mobile robots concurently, for example in a factory floor.

In fact, we designed an experiment to control a mobile robot and a manipulator in a unloading task. In the experimental design, a mobile robot was following a gradient source to reach a place where a manipulator is located. The stop point for a mobile robot is defined by a specialy designed platform which tells the central computer that the mobile robot is "at the right place". The central "factory" computer, in our case Series/1 computer, activates the manipulator which in turn, unloads the mobile robot. After that the mobile robot performs a turn routine to leave the platform, and is in stand by position to follow another beacon. The central computer then decides which of the several beacons to activate, and consequently, to send the mobile robot in a desired direction. [4,6,7]

Speech control

We used previous designed mobile robot to control it by speech commands. Five command system was designed, to respond on start, stop, left, right, and back command. The method used was formant method. [11]

Neural network control

All the above reported experiments were carried out with physical models. The fixed rail control is an industry application, and the others are laboratory experiment.

Our work with neural network control is a computer simulation work. A CAA neural network controller is used as an unsupervised problem solver, which is able to build a model of the environment the mobile robot moves in. The environment is represented by a emotional graph, a maze where the robot recognizes desirable and also undesirable situations. The CAA neural net controller was also demonstrated as controller for a benchmark task of pole balancing control [2,5].

Bioelectric Mobile Robot Control

In this part of the paper a description of a bioelectric control experiments is given. First we describe the biosignals which we are using, then the control algorithms and finaly the experiments carried out.

Control biosignals used: EEG and EOG

The biosignals we used in our investigation are EEG signal taken from the occipital region where usualy alpha rhythm is recorded, and EOG signals taken from the eyes movement. The signals are obtained using biomedical amplifier, 14-bit A/D converter, PC/XT computer, 100 Hz sampling rate, and our signal processing software.

Figures 1 and 2 give examples of these signals (lower part) with segment enlargement (central part of the figure).

Figure 1 shows change of the EEG activity when the operator opens and closes his eyes.

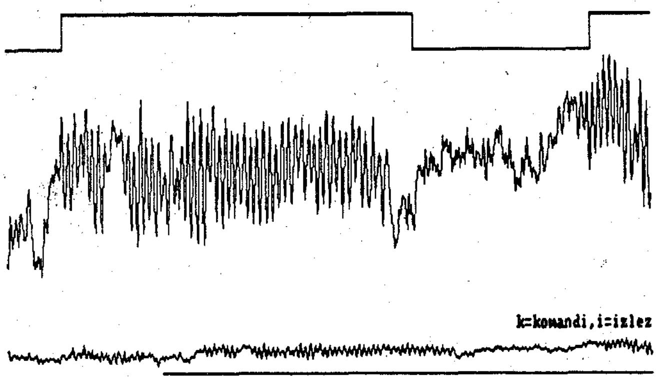

Figure 1. Example of an EEG activity during open and closed eyes (lower and central part) and performance of the closed-eyes recognition algorithm (upper part)

Figure 2 gives a pattern of the EOG activity during the eyes movement: up/down, left/right, and winking.

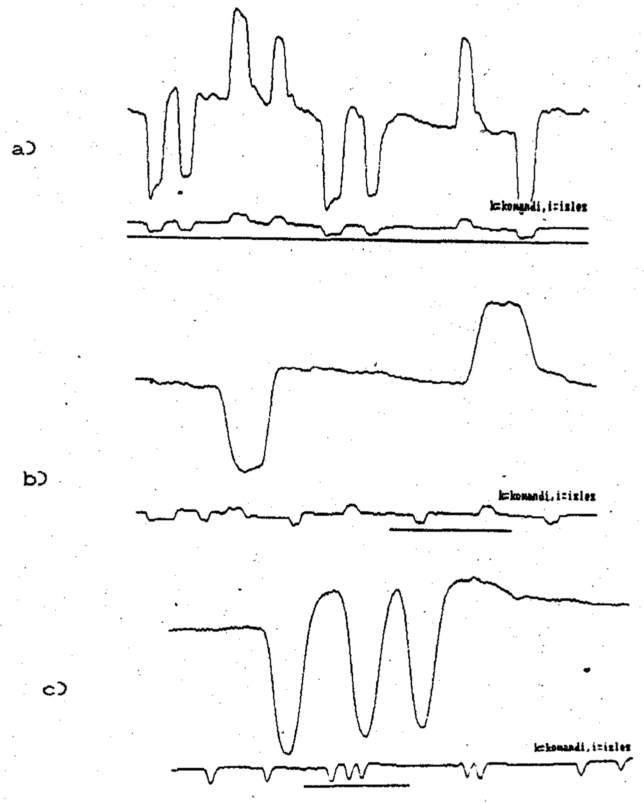

Figure 2. EOG activity due to the eyes movement: Fig 1.a) up/down Fig 1.b) left/right Fig 1.c) winking

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Procedure Learning:
     Perform 10 sec Acquisition
       during which
         the operator has eyes open;
     Compute distributions for
       the time intervals betweeen two extreme points, and
       the amplitudes of those points.
 Perform Procedure Learning
     replacing "eyes open" with "eyes closed".
 Compute decision border points
     for the pairs of distributions
     for "open" and "closed" case.

Procedure examination:
While the operator opens and closes his eyes in real time do:
     Perform Acquisition until a next extreme point is found,
         compute its time interval
         compute its amplitude;
     Compare with the respective "open"/"close" distributions
         if they fall in "open" region
            vote "open"
            increment open-counter
            reset close-counter
            if open-counter=required_votes
               then decision="OPEN";
         if they fall in "close" region
            vote "close"
            increment close-counter
            reset open-counter
            if close counter=required_votes
                then decision="CLOSE";
```

Figure 3: The EEG control algorithm

The control algorithms

To perform control using the mentioned signals, we designed a control algorithms which are able to recognize the appropriate patterns of the bioelectric activity. The patterns are sensitive to the human operator who generates them, so it was neccessary to design them with ability to *adapt their parameters* to the considered human operator. The adaptive control algorithms we designed have three working regimes: *learning regime, examination regime, and exploatation regime*. The exploatation regime is actualy the real-time control of the robot, with the decisions described in the examination regime.

The EEG control algorithm. The EEG control algorithm given as a pseudo-Cobol procedure is shown on Figure 3. In our experiments, the parameter *required_votes* was set equal 3. The performance of this algorithm for a given EEG pattern is shown on the upper part of the Figure 1.

The EOG control algorithm. The recognition procedure of the EOG control algorithm during its examination procedure is based on the observation that the EOG amplifiers measure actualy the projection of the eye dipole vector to the line defined by the electrodes (Figure 4). That gives the same polarity for "down" and "wink", but the winking can be distinguished that it is significantly faster (fastest human movement).

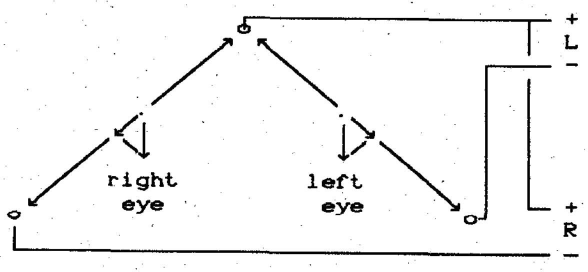

Figure 4. The EOG amplifiers measure the eye dipols projection. It is showh a case when the sight points down

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Procedure Learning:
    Perform Acquisition during which
      the operator moves the eyes "up",
      store values for "up".
    Perform Procedure Learning
      replacing "up" with "down","left","right","wink".

Procedure Examination:
    While the operator moves his eyes in real time do:
        measure the amplifiers values L and D
          from the left and the right eye respectively,
          and the frequency F of the signal between L and D;
        if L="PLUS" and D="PLUS" decision="UP"
        if L="PLUS" and D="MINUS" decision="RIGHT"
        if L="MINUS" and D="PLUS" decision ="LEFT"
        if L="MINUS" and D="MINUS"
                if F="LOW" decision="DOWN"
                if F="HIGH" decision="WINK".
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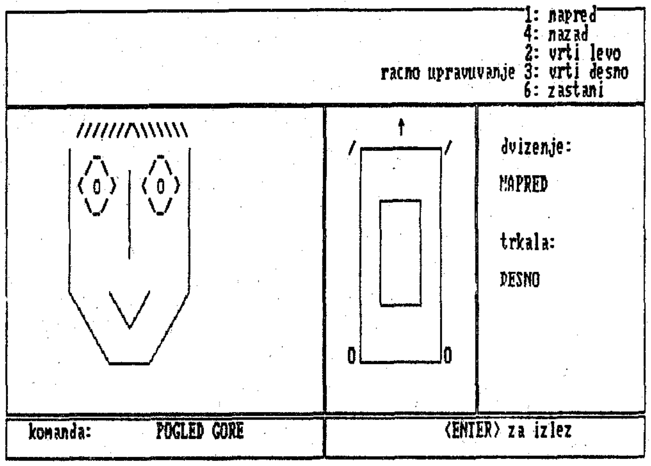
Figure 5. The EOG control algorithm

The complete EOG control algorithm is described on Figure 5, using a pseudo-Cobol language.

Figure 6 shows the animation software during the real time experiments (exploatation regime of the EOG control algorithm). The screen shows both the eyes movement and the robot movement in animation mode.



dvizenje: NAPRED

trkala: DESNO

komanda: POGLED GORE

Figure 6. Animatied representation of the mobile robot control during the exploatation regime of the control algorithm

The experimental design and the experiments

Our experimental investigation is based on the experimental design given on Figure 7.

The exploatation modules of the control algorithms perform the appropriate mapping between the recognized eyes movement and robot action.

The EEG control experiment includes an Elehoby Line Tracer mobile robot which has its own intelligence to follow a black trajectory drawn on a white floor. The operator performs start/stop control during the robot movement along the trajectory, by stopping the robot when he opens his eyes, and continuing robot movement as long as the eyes are closed.

The EOG control experiment includes a mobile robot which we designed for our investigation with various modes of robot control mentioned above. On a terrain with obstacles, the operator has a task to lead the robot from a starting to a goal point using five command (Forward, Bacward, Left, Right, Stop), given by his eyes movement (Up, Down, Left, Right, Blink).

The experiments are carried out with various subjects, students of the subject Robotics and biocybernetics, ninth semester of the Computer Science Division of the Electrical Engineering Faculty. The average time a student to be trained to successfully perform a control task is 30 min.

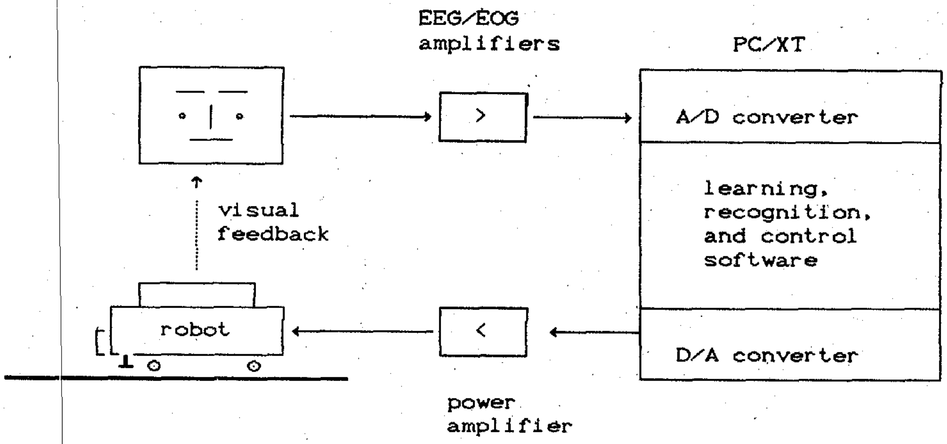


Figure 7. The experimental design

Conclusion

We reported about our effort to show a possibility of control a mobile robot using signals from the human head. The experimental result have confirmed our expectation on possibility of robot guidance using such a control signals. Until now we experimented with simple EEG and EOG signals. Our further effort will be in design a helmet which will enable other head signals also to be used in robot control.

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