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Hands-free Operation of a Small Mobile Robot *

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Abstract

The Intelligent Systems and Robotics Center of Sandia National Laboratories has an ongoing research program in advanced user interfaces. As part of this research, promising new transduction devices, particularly hands-free devices, are being explored for the control of mobile and floor-mounted robotic systems. Brainwave control has been successfully demonstrated by other researchers in a variety of fields. In the research described here, Sandia developed and demonstrated a proof-of-concept brainwave-controlled mobile robot system. Preliminary results were encouraging. Additional work required to turn this into a reliable, fieldable system for mobile robotic control is identified. Used in conjunction with other controls, brainwave control could be an effective control method in certain circumstances.

Introduction

Starting in 1980, Sandia National Laboratories in Albuquerque, NM, has developed a variety of mobile robot systems. . Recently the Intelligent Systems and Robotics Center has been exploring advanced user interface concepts for mobile and floor-mounted robotic systems.

We desired to control the speed and direction of movement of a small mobile robot, while in direct visual contact with the robot, but without use of the hands. Brainwaves (electroencephalogram, EEG) and muscular movements (electromyogram, EMG) have been demonstrated in a variety of control applications. These include control of virtual aircraft [3], computer software [5] [7], and robotic arms [1]. Applications for the disabled have also been demonstrated in [2] and [6]. With this basis, we built and tested a proof-of-concept system based on a commercially available device, the CyberLink™ MindMouse, to use brainwaves and small facial muscular movements to control the speed and direction of the robot.

System Description

A small mobile robot was controlled by wireless radio from an operator control "station." The system included the following hardware elements:

1. CyberLink™ MindMouse input device with electrode headband.
2. Pen-based computer for translating MindMouse data into robot commands.
3. Radio transmitter, powered by a battery belt, for sending commands to the mobile robot.
4. A Sandia-developed Mini-RATLER™ mobile robot. (See Figure 1.)

The operator wore the MindMouse, pen-based computer, radio transmitter, and battery belt, which comprised a completely portable control station. This configuration allowed the operator to follow the robot while driving in order to maintain direct visual contact with the robot.

The MindMouse is shipped with software for training the operator to use brainwaves and small facial movements. The operator used this software, which included challenging programs such as a labyrinth and MindTetris, to become proficient in using EEG and EMG to control a cursor on the screen.

Encouraged by this success, we wrote custom software to translate MindMouse data into mobile robot commands. After assembling the system hardware and software, we began initial testing of the system. As a result of those tests, we determined a reasonable way to map input actions to the desired control actions. Table 1 shows the

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mapping between the physiological input and the desired robot command.

Table 1. Mapping of physiological input to robot commands

Physiological input	Robot Command
Beta wave amplitude	Vehicle speed corresponds to brainwave amplitude
Jaw clench	Toggle forward and reverse direction.
Look left / look right	Perform 30-degree turn in corresponding direction.

During our early tests, we used the "raise eyebrow" action to toggle between forward and reverse. An electrical noise problem caused many of these commands to be sent in succession for just one eyebrow raise. Later, the "jaw clench" action was used in place of the "raise eyebrow" action. (Swallowing had the same result as a jaw clench, so our belief is that any lower facial muscular tension would be interpreted similarly.)

To generate a "look left / right" action, the operator first looks from center to the left or the right, and then returns gaze to center. Custom software was developed to filter the eye muscle signals (electrooculogram, or EOG) in order to recognize the look left / right action. This action is a discrete event as opposed to a continuous state, so each look left / right action triggered a robot command for a programmed 30-degree turn in the corresponding direction.

Results

We were successful in controlling the robot speed and direction without the use of the driver's hands. The mapping of beta wave amplitude to throttle commands was excellent for controlling robot speed proportionally. While, the programmed 30-degree turn did not provide fine directional control, especially with the skid-steered robot on variable floor surfaces, it was sufficient to show that the look left / right commands were being interpreted correctly.

There were several minor problems in our initial implementation. For example, the robot did not respond to the "jaw clench" action immediately. There was an unexplained delay of approximately one minute from each clench action, during which the operator usually issued several more jaw clenches because nothing had happened. When the commands were finally executed much later, there were several reversals of direction in succession.

The main problem, however, with this configuration is that you cannot "turn your brain off." For example, if the operator is asked a question or engaged in dialog during a demonstration, the actions of the brain affect the response of the vehicle. In order to drive the vehicle effectively and have any ability to attend to other activities, additional controls such as a switch to indicate operational context (e.g., "I'm driving now") would be necessary. The current implementation requires great concentration by the operator, and distractions easily affect the desired performance of the robot. During demonstrations to more than three people at a time, it was not apparent to the observers that anything other than random commands were being sent to the robot! In smaller demonstrations to one or two people in the laboratory, robot control could be shown, especially if the operator were seated and the robot was "up on blocks," stationary on the lab bench but with the wheels free to move.

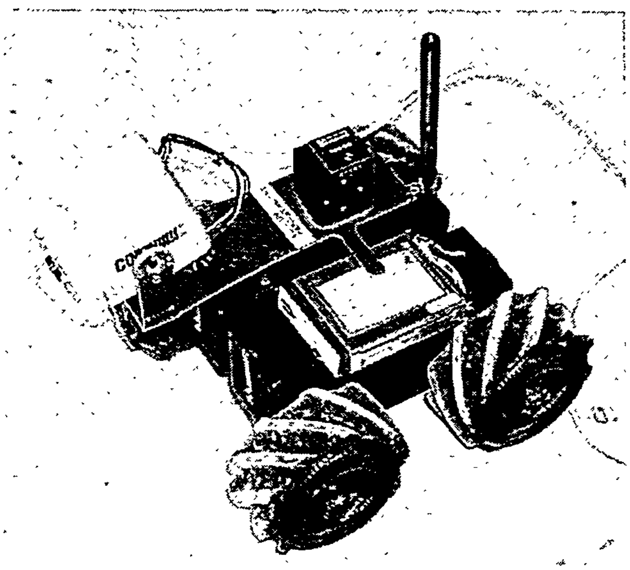

Figure 1. Mini-RATLER™ robot.

Conclusion

Overall, we learned several things from these initial experiments. We were successful in initial operation of the small mobile robot "hands-free". While we were not able to achieve fine control of the robot, we are confident that it can be done given the success with the MindMouse training suite. We learned that the use of hands-free controls requires a heavy investment in operator training, and this aspect of achieving successful operation should be considered strongly before application areas are further explored. Additional controls, such as a switch to indicate operational context, would need to be added to make this particular system more usable. Future work is needed to make this a successful system that could actually be used reliably in the field. Such work should include structured experiments, additional switching controls as mentioned above, and software refinement, in both signal processing and controls software.

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To Whom It May Concern:

This TCM2-50 model (SN 6585   Ver 2.34) is being returned on RMA #17932 due to poor compass performance. After several attempts to calibrate the compass successfully it was determined that the compass is off. After the compass is calibrated, it indicates north correctly (in comparison with a hand-held magnetic compass) when the module is rotated 90° (facing either east or west) it may read up to 20° off when compared with the hand-held compass. Calibrations were done outside away from any ferrous metals or artificial magnetic fields.

Please contact Clinton G Hobart at Sandia National Laboratories at (505)844-1519 if you have any questions.

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