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The Control System Based on Extended BCI for a Robotic Wheelchair

Timofei I. Voznenko*, Eugene V. Chepin†, and Gleb A. Urvanov

National Research Nuclear University MEPhI (Moscow Engineering Physics Institute)
Moscow, Russia

Abstract

In most cases, the movement of wheelchairs is controlled by disabled people using a joystick or by an accompanying person. Significantly disabled patients need alternative control methods without using the wheelchair joystick because it is undesirable or impossible for these patients. In this article, we present the implementation of a robotic wheelchair based on a powered wheelchair that is controlled not by the joystick but by the onboard computer that receives and processes data from the extended brain-computer interface (extended BCI). Under this term we understand the robotic complex control system with simultaneous independent alternative control channels. In this robotic wheelchair version the BCI works with voice and gesture control channels.

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Keywords: extended brain-computer interface, robotic wheelchair, control channel, robotics

1 Introduction

Technical projects on the development of robotic wheelchairs have been carried out since the last century. Modern mobile robotic complexes (MR) which include robotic wheelchairs are complex heterogeneous hardware and software systems and they should provide a certain level of comfort and reliability of control answering the fields of their application. Under the term MR we understand the robotic system having an onboard powerful, versatile, and inexpensive miniature computer with a modern CPU providing the ability to connect the modern peripherals to the system without any restrictions, unlike the microcontroller capabilities. Because of this, it is possible to use the maximum possible set of software, more memory and parallel programming techniques to achieve the real-time mode (RTM).

The robotic wheelchair (hereinafter the "chair") is designed for patients with severe disorders of the musculoskeletal system and other functions of the body (hands, speech, hearing, etc.). The patient is the operator of the chair sitting in it and controlling it via the control system. For

*Corresponding author. E-mail address: snaipervti@gmail.com
†Corresponding author. E-mail address: evchepin@gmail.com

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clarity we will call them the "patient". Along with it, the chair is controlled by the specialist-operator who can remotely monitor the chair. This is possible because of a parallel chair-control channel provided by the Wi-Fi connection of the onboard computer with a remote Tracking and Control Station (TCS). TCS is a remote computer through which the specialist-operator can control the chair "intercepting", if necessary, the control from the patient-operator.

2 Related Works

The patients who use the wheelchairs in most cases are quite satisfied with them, if the chair is equipped with an electric drive and control system via the joystick. An example of such a robotic wheelchair called Wheelesley is described by Yanco [1]. This chair provides additional opportunities for the patient during the driving by the provision of the information "with a lower level of navigation".

One of the modern trends in the development of the robotic wheelchairs is the projects such as the Chinese project Chiba (Robotic wheelchair) described by Morales et al. [2] and Szondy [3]. The main objective of these projects is the control system of the mechatronics of the chair which effectively overcomes the obstacles in the way such as stairs and border stones. However, some patients are unable to control the chair with such functions. Therefore, for these patients the way to improve the quality of their lives is the development of the control systems for the robotic wheelchairs that would allow them to control their own wheelchair using their modest possibilities: weak hands, voice, etc.

There is a great variety of the ways to control the MR. The most common is to control directly by the joystick as described by Jawawi et al. [4]. However, the directly connected to the servomotor of the joystick Arduino opens the opportunity of controlling the chair using such methods as the brain-computer interface (BCI), voice or gesture control. Each MR has onboard a powerful general-purpose computer. It interacts during the operation with the external computing unit — Tracking and Control Station (TCS). The TCS allows to carry out the remote control of the MR's work by the operator. Also, it is possible to send to the TCS the data to gather the statistics on the basis of which it is possible to make the changes in the values of the parameters to improve the quality of the MR's control.

The global problem of increasing the intelligence of such complex systems is extremely relevant nowadays, especially in the transition to the control of the teams of robots, for example proposed by Bereznyak et al. [5]. For some applications of the MRs their control circuit includes a human-operator. For example, in medicine it is extremely important to implement the control system based on the traditional paradigm of "control commands", but on the basis of non-traditional methods of controlling the complex systems.

There are several works describing BCI-controlled wheelchairs but the control accuracy is not high enough for reliable control, for example, 50% and above described by Ng et al. [6] and 79.38% presented by Achic et al. [7].

In order to increase the control accuracy of BCI-controlled robotic wheelchair we propose using of other control channels like voice commands or gestures. In this project, we proposed the new non-traditional control method we called "extended BCI", which involves the operation of three control channels in parallel: voice commands, gestures and the BCI. The urgency and necessity of this control method is determined by the field of its application: medical robotics.

3 Theory

3.1 The Nontraditional Methods of MR Control

Under the traditional method of MRs control we understand the way to control using the commands passed from the operator to the MR's control system via some interface. Under the non-traditional control methods we understand in this article the following: BCI, voice control, control with gestures.

The BCI is an interface that provides a direct transmission of the information from the brain to the computing device as described by Tromov and Skrugin [8]. Recently different companies has developed the portable BCI such as NeuroSky, MindFlex, Emotiv, as described by Stamps and Hamam [9]. Some of these neurocomputing interfaces allows not only to obtain the EEG (electroencephalogram) data, but also to obtain data about the emotional state of the operator, for example used by Chepin et al. [10] and Voznenko et al. [11].

The voice control is a way of interaction between a man and a computer by the voice. This method of control is based on the processing of audio signals coming from a microphone. Speech recognition system using phonemes and grammar follows Lamere et al. [12].

The gesture recognition system was developed by Chistjakov et al. [13] in the "Robotics" laboratory of the NRNU MEPhI. The algorithm determines the fact of the hand getting in the graphics region (specified area) corresponding to a particular gesture. This system is installed into the wheelchair to control its movement by the hand gestures and finger movements of the patient.

3.2 Extended BCI

The main scientific and engineering idea of the described project is the development of the control system. The general ideology of the project is based on the concept of "extended BCI" proposed by Tromov and Skrugin [8], Dyumin et al. [14], Chepin et al. [15] and Urvanov et al. [16], by which we mean the presence in the control system the following robot-control channels: BCI, voice control, control with gestures.

The term "extended BCI" was introduced in order to emphasize that in addition to the control channel based on the parallel BCI there are other ones, not so common channels. BCI is the main control method, but in practice there are situations when a particular patient more effectively controls the wheelchair using the voice commands and/or gestures. With this approach, it is necessary to solve the problem of choosing the most correct control channel. In addition, the architecture should implement the possibility of taking into account the disease peculiarities of the particular patient and develop a decision-making mechanism based on the analysis of the information from all control channels.

3.3 The Task of Decision-Making

The concept of "extended interface" includes several different control channels of the MR by the operator. The general scheme of the decision-making system based on the data from the extended BCI interface is presented in Figure 1. When using more than one data channel to control the MR it is needed to solve the problem of the decision-making. In general, the problem looks as follows: there are several control channels and it is necessary to decide what command should be executed at a given time. The decision-making system should have the following features:

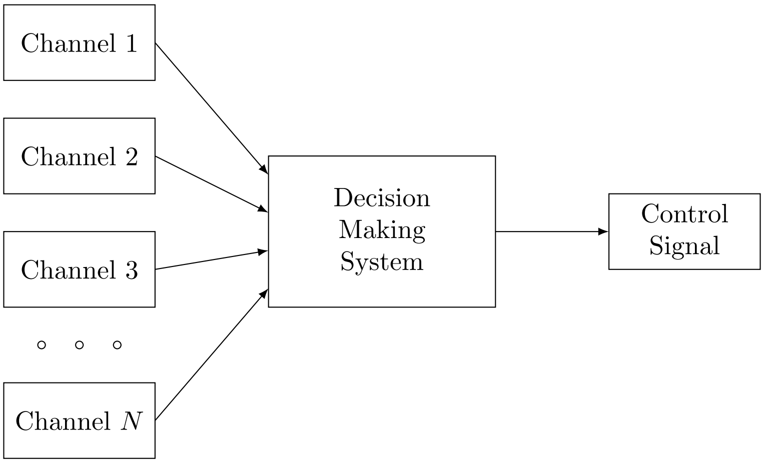

Figure 1: General problem statement

1. To be deterministic. If we know the specificity of working with the extended BCI-interface system components it is possible to make the deterministic decision-making system taking into account the mentioned features of the components.
2. The ability to have the varying credibility degree for the control system channels . Since the channels have different degree of credibility, it is logical that the information coming to the decision-making system should have the different values.
3. Support an asynchronous data input. Despite the fact that the part of the data is received synchronously and during a long period of time, the solutions based on asynchronously incoming information having a greater relative value should be taken timely.
4. Work with continuous processes. For example, when working with thought-images it is important to record not only the state but also the dynamic characteristics of the process, and the previous state. Thus, the developed method of decision-making should be similar to the automaton with a memory.

The decision-making system prototype satisfying all requirements was implemented using channels accuracy based priority accounting.

4 Implementation

The current "chair" hardware-software complex consists of:

1. The wheelchair with the electric drive "Titan" LY-103-120, which is designed for the independent movement in the premises and on roads with hard-surface for the disabled people with diseases of the musculoskeletal system and injuries of the lower extremities (Figure 2a). Instead of joystick control the chair has a control unit, which has an interface with the onboard computer port.
2. The neural interface on the basis of the Emotiv Epoc (Figure 2b) and the software module. The Emotiv Epoc BCI allows one to obtain information not only about the fact that the user thought about the thought-images, but also the quantitative assessment of this fact (power).

Figure 2: a) The “chair”, b) BCI Epoc Emotiv, c) Intel RealSense

3. The basic equipment for the operator video interface with the robot for the development of a system of gesture recognition (a stereo camera for fixing the movements and gestures of the operator and the set of individual cameras). The arm tracking is made using an Intel RealSense camera that is shown in Figure 2c.
4. The basic equipment for the operator audio interface with the chair. The voice recognition takes place with the help of English phonetics of the Sphinx-4 library developed by Lamere et al. [12]. The dictionary consists of the words matched the available phonetics.

5 Results and Conclusion

The “chair” project has received quite a wide coverage in Russian and the foreign mass-media: a few reports on some Russian TV-channels, in particular, on the NTV [17], as well as in the press of Spain and Spanish-speaking countries, for example in El Diario de Hoy [18], El Universal [19] and in China (Science and Technology Daily [20]).

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