Robotic complex for the development of thick steeply-inclined coal seams and ore deposits

M S Nikitenko[1], Yu V Malakhov[1], Biswarup Neogi[2], Pritam Chakraborty[2] and Dipesu Banerjee[2]

[1]Federal Research Center of Coal and Coal Chemistry, Siberian Branch of the Russian Academy of Sciences, 18 Sovetskiy Ave., Kemerovo, 650000, Russia
[2]CoE & CII Centre for Innovation , JIS College of Engineering (JIS Group India), Block A, Phase III, Dist. Nadia, Kalyani, West Bengal, 741235, India

E-mail: schum24@rambler.ru

Abstract. Proposal for the formulation of robotic complexes for steeply inclined coal seams as a basis of the supportive-enclosing walking module and power support with a controlled outlet for mining industry has been represented in this literature. In mining industry, the available resource base reserves and mineral deposits are concentrated deep down the earth crust leading towards a complicated geological condition i.e. abrupt ore bedding and steeply inclined strata with the high gas content and fire hazard of thick coal stratum, heading against an unfavorable and sometimes human labor life risk during subversive mining. Prevailing towards the development of effective robotic complexes based on the means of “unmanned technologies” for extraction of minerals from hard-to-reach deposits and make sure the safety of underground staff during sublevel mining technology.

1. Introduction

Advancement of mining industry and the improvement of mining safety structure depend critically not only on the use of new different types of equipment and technologies, dispatching and automation of mining complexes’ control, but also on the accelerated conception and widespread introduction of unique automated mining control systems based on fully or partially robotic technology provides a platform for implementation of “unmanned” technology [1, 2].

On contemporary, existing equipment used in mines are ineffective for the extraction of mineral deposits from abruptly inclined stratums, and it does not work without supervision of constant human labor at extraction and preparatory faces, thus there is an urge need of modern technology keeping in view the stimulating geological circumstances, along with subversive mine gas and dust generating a need for the development of “unmanned" mineral extraction technology [3]. In connection with the foregoing, there is also a need to develop new technical solutions for the extraction of minerals from steeply-inclined coal strata and ore materials [4]. The newly developed technological schemes [5] and technical facilities [6 - 8] will allow creating robotic complexes for mining and mineral deposits (coal, diamond ore, etc.) with fewer hominid labor and with high efficacy with a control system that works considering the rock conditions and its dynamic manifestations.

Presently in coal industry lacks high-performance coal extraction mechanized complexes for effective, safe underground method development of thick steep and steeply-inclined coal seams. Therefore, due to the lack of appropriate mining equipment subversive mining in Russia is still old-

fashioned leading to unutilized coal stratums, although they contain more than 50 % of industrial coal reserves, including valuable coking grades.

As per Order of the Ministry of Industry and Trade of the Russian Federation No. 654 of March 31, 2015, approved plan of measures for import substitution in the heavy engineering industry of the Russian Federation, in which the creation of domestic automated extraction complexes was recognized as the priority among mining equipment. The share of imports in their consumption in 2016 was 100 %. In addition, the development of complexes and conveyor transport control systems was recognized as a priority, with the share of imports in consumption of which in 2016 was 80 %. As part of the approved long-term program for the development of the Russian coal industry until 2030, approved by the RF Government Decree of 24.01.2012 No. 14-p, the main direction of technological development with respect to the underground mining method is the implementation of measures to develop and implement systems of "unmanned" minerals extraction on the basis of complex mechanization and automation [9].

In 2016, forecast of the scientific and technological development of the fuel and energy complex of Russia for the period of 2035 developed by the Ministry of Energy of Russia, and in the list of 24 priority critical technologies were included - coal mining technologies without the constant presence of people in the working space (robotic complexes for development of thin and steep seams with high selectivity).

2. Methods of research

Proposed robotic complexes based on supportive-enclosing walking module and KPV power support with controlled outlet as an effective technological solution capable of ensuring the steep and steeply inclined coal seams underground method development. The weakening of the let out coal massif is supposed to be carried out by safe methods - by means of its stepwise directed hydraulic fracturing or by vibro-seismic method (seismic vibrators). In this method of working out coal seams, explosives are not used. The proposed technological solutions create the transition basis to "unmanned" mining technologies.

The actuality of the proposed technical solutions is caused by the following:

- the inconsistency of the used traditional shielding steeply inclined seam coal extraction technology to modern requirements of the Federal Safety Standards and Regulations for mines with high seam gas content [10];
- the orientation of the coal industry and domestic coal machinery on the technology of "unmanned" productions. In comparison with the low-efficient traditional shield method for working out thick, steeply-inclined coal seams and alluvial ore bodies (materials), the robotic complex based on the supportive-enclosing walking module and the KPV power support with controlled outlet has the following main advantages:

1. Creates the basis for the introduction of a robotic method of mineral mining by underground method (unmanned technologies).

2. Provides a high level of safety (there is no manual labor, no explosives are used to weaken the massif of minerals).

3. High degree (up to 80 %) of minerals extraction from seams (otherwise it can be said that it reduces the mineral resources extraction losses by half).

4. Rapidly readjustable, complex design reusable layout. Convenient transportation.

An additional direction of using a supportive-enclosing walking module can be the creation on their basis of a robotic mine rescue complex for the MChS Militant Mine Rescue units.

"Unmanned" technologies – this is a conventional name for ways to organize technological processes without the direct presence of a person in the place of their implementation.

The main advantages of using "unmanned" technologies:

- exclusion of people from places with dangerous and harmful working conditions;

- the opportunity to work with such parameters of mine workings that are prohibited under safety conditions when people are located there, which makes it possible to ensure a higher efficiency of mining;
- possibility to control machinery being at a very large distance from it, which also allows solving the concomitant problem of delivering a large number of people to remote areas;
- equipment productivity increase due to more accurate and optimal control of equipment.

The use of "unmanned" technologies for the mineral extraction is provided by the use of robotic complexes' automated control systems.

Concerning the depth of automation and functionality of underground mining robotic complexes control system it is proposed to implement at several levels:

- "dispatching system" – a set of software and hardware means that allows remote monitoring and control of engineering systems of one or more robotic complexes (remote control);
- "system based on adaptive technologies"
- automatic control (maintenance in specified ranges) process parameters functions transfer to the software and hardware complex, with the operator's ability to remotely perform their direct control from the control station;
- "Brain computer interface (BCI) control system" – a perspective system of adaptive automated control, with the possibility of remote control based on the mind control technology "Mind control" or "Concentration control". Human thought, the interaction between brain neurons, creates various electrical waves, generating a unique electrical signal. These electrical signals are determined by the brain wave sensors, the data is converted into packets and transmitted via Bluetooth to the level analyzer unit (LAU).

The analyzer block receives raw brain data, extracts and processes the signal using the Matlab platform. The control commands are then transferred to the robotic module for processing, thus controlling the movement and transferring functions. The application of these technologies will allow providing direct communication and control between the human brain and physical devices by transferring the brain activity structures and commands in real time and implementing on their basis the control systems for mechanized complexes and control of auxiliary systems (initiation of outlet, loading, manipulators, etc.) depending on the tasks assigned.

Several researchers familiarize the future aim of the BCI technology for the different kinds of application aspects. Joseph N. Mak et. al [11], Mikhail, A. Lebedev et. al [12], Petrov et.al [13] subsidized future prospects of BCI considering industrial and ergonomic advancement. One phase in advance, the stage will be commenced for sophisticated Internet of Things (IoT) based technology and Brain Computer Interface (BCI) amalgamation research. The present research illustrated with two parts introducing high end mining device association with brain control interface (BCI). The platform of these two annexes is presented as novelty research theme. This extent will carry its importance as interlinked stage of IoT and BCI implemented in mining industry [14 - 16]. Limited researches are even now presented, allied mining technology and BCI.

Application of BCI technology has found a wide span from medical prosthetics to artificial robotics in industrial automation. Presently researchers are widely interested to extend the support of BCI technology in the mining industry where the geological surroundings are incompatible for extraction of minerals deep down the core [17].

In JIS Collage of Engineering (West Bengal, India), Neogi et. al contributed some of ideas involving BCI technology which can be incorporated together towards the Mining Industry Automation [18]. The specialists have already mastered the basic modules of the motion control system [18]. The intellectual device Concentration control Switch, Cognitively velocity controlled car and Mind control artificial arm are mainly ergonomic devices developed. In the framework of joint work of JIS College of Engineering and Federal Research Center for Coal and Coal Chemistry of the Russian Academy of Sciences Siberian Branch started to integrate them into the control system of the robotic complexes based on the support-enclosing walking module and KPV power support with controlled outlet.

3. Results and discussion

3.1. Concentration Control Switching System

In view of contemporary sovereign technological procreation this innovative discovery relates to a concentration control switch system based brain computer interface (BCI). Furthermore, this innovation relates to the switching of various electrical appliances and electronic industrial devices through concentration wherein brain computer interface can circumvent predictable channels of communication to arrange for direct communication and control between the human brain and physical devices by decoding diverse configurations of brain activity into directives in tangible interval.

The prime embodiment of the innovation is to provide a concentration controlled switching system based brain computer interface (BCI) in procuring volatile, cultivated and technically manufactured contemporary customary appliances that could end up to the switching of various electrical appliances and electronic industrial devices through concentration. The further focal object of the innovative discovery is to provide the concentration controlled switching system wherein brain computer interface can bypass conventional channels of communication (i.e., muscles and thoughts) to provide direct communication and control between the human brain and physical devices by translating different patterns of brain activity into directives in real time.

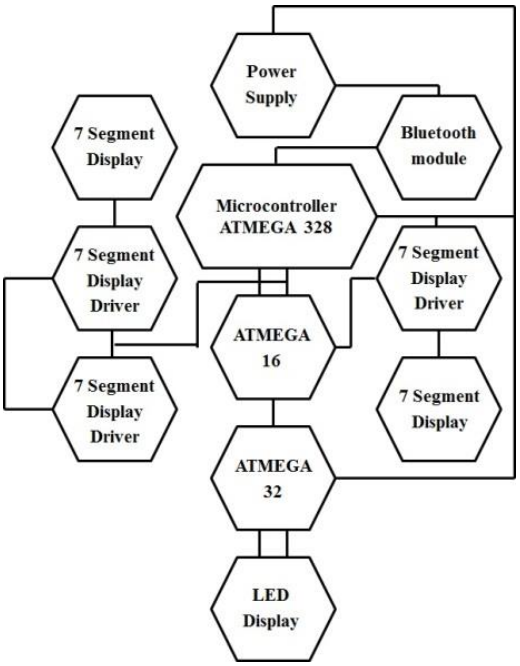


Figure 1. Circuitry block representation of concentration control switching system.

The proposed technology can be utilized in underground mining lighting of robotic complex for proper navigation during mineral extraction.

3.2. Cognitively Velocity Controlled Vehicle

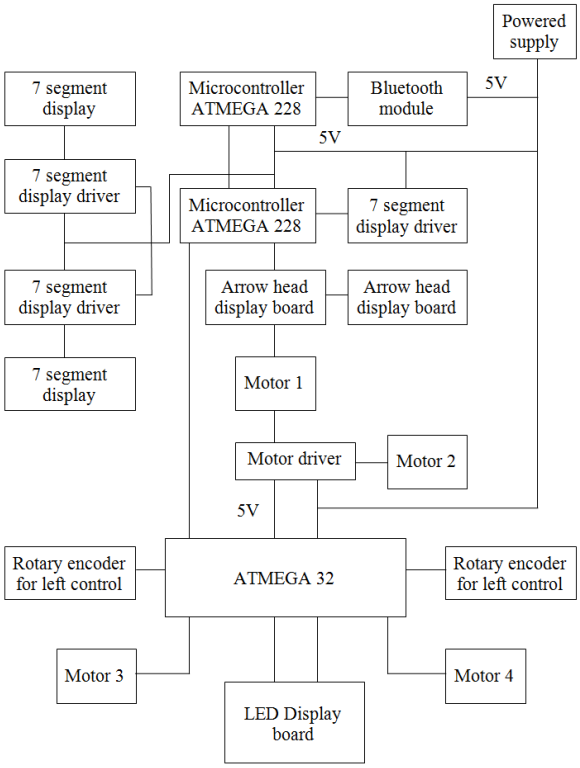
This innovation relays a cognitively velocity controller vehicle which is a mind controlled cognitive vehicle based brain computer interface (BCI). Additionally, this also relays cognitively velocity controller vehicle wherein brain computer interface can sidestep conservative networks of communication (i.e., muscles and thoughts) to provide direct communication and control between the

human brain and physical devices by translating different patterns of brain activity into commands in real time.

The foremost purpose of the idea is to afford a cognitively velocity controller vehicle. The additional incarnation of the innovation is to offer a cognitively velocity controller vehicle which is a mind controlled cognitive vehicle based brain computer interface (BCI).The origination is to provide the cognitively velocity controller vehicle wherein brain compute interface can bypass conventional channels of communication (i.e., muscles and thoughts) to provide direct communication and control between the human brain and physical devices by translating different patterns of brain activity into commands in real time. The supplementary embodiment of the invention is to provide the cognitively velocity controller vehicle which can control up to four types of orientations of movements-right, left, forward, backward but if there is a suitable arrangement it can control clock wise and anti-clock wise rotation also.

(a)

(b)



(c)

Figure 2. Prototype of a cognitively velocity controlled vehicle (a), working overview at JIS University Lab (b), schematic flow-chart representation of the cognitively velocity controlled vehicle (c).

Incorporation of the proposed methodology in relation to mining industry would enable to reach the steeply inclined coal seams for extraction and diagnosis of the stratum geological conditions for extraction of minerals during sublevel mining.

3.3. Thought Concentration Controlled Dexterous Mechanic Arm

This origination shares to a thought controlled dexterous mechanic arm. This shares to a thought controlled dexterous mechanic arm which can be operated by a brain-computer interface (BCI) that enables communication between brain activity and an external device (arm).

This creation narrates to thought controlled dexterous mechanic arm which can be activated by a brain-computer interface (BCI) that empowers communication between brain activity and an external device. Entity of the invention is to provide a thought controlled dexterous prosthetic arm which consists of a) the gripping with concentration, b) A lever appliance is used for opening and closing the gripper; c) a single DC motor for the gripper control.

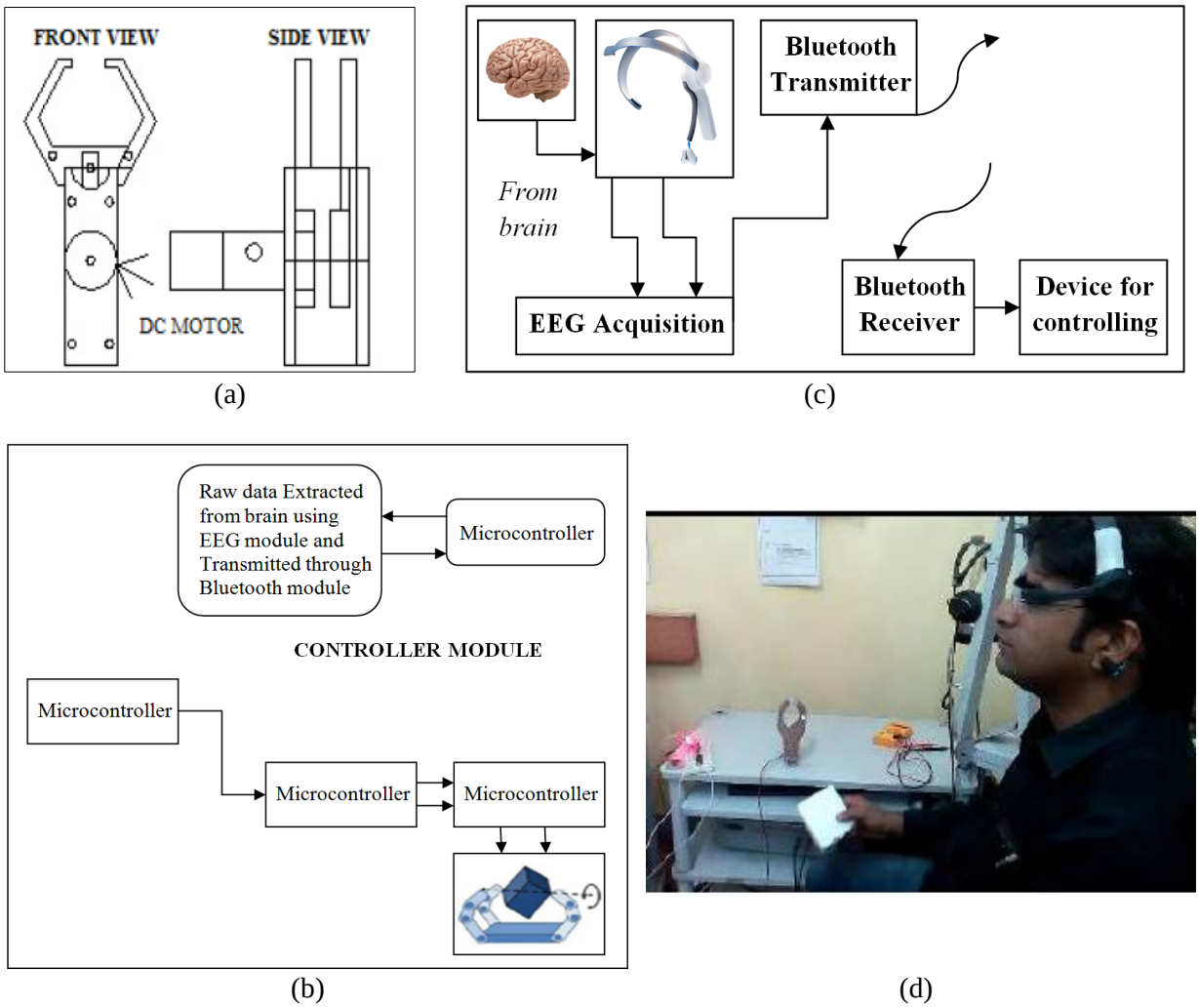


Figure 3. Schematic diagram of thought controlled mechanic arm (a), BCI interface schematic module (b-c), working overview at JIS University Lab (d).

The epitome of the invention is to provide a thought controlled dexterous mechanic arm which has the beneficial effects of having saving manpower cost, reducing labor intensity, and having safety and reliability which can be further applied in mining industry during underground mining mineral extraction with high efficacy. For example development of a manipulator to intensify the top coals caving process and other tasks.

4. Conclusions

The support-enclosing walking module and the KPV power support with controlled outlet are the basis for creating robotic complexes for the safe development of stratified mineral deposits with the underground method, which provide working out of seams with complicated mining and geological

bedding conditions (steep and steeply inclined thick seams). The control system of the robotic complex provides adaptive-program systems of the complex functional elements without people constant presence at the extraction face.

The technological theme of the Indian project attempt is to introduce in coal mining part / others mining parts in Russia with technology transfer vertical. Safety is one of the major consideration points for mining. The safety matter will be instigated with effort of BCI technological upbringing. All the coal mining technologies are under review stage en route for the intention of suitable implication of IoT based BCI skills. Robotic based unmanned application of walking module and the KPV power support with controlled outlet are already initiated as joint collaboration. Control strategy with performance analysis introducing controllability & observability testing are additional objective of the future for this research. In addition, the nonlinearity analysis will be the best challenge of this research in upcoming future after developing error less system based MIMO approach. Moreover, the research as interlinked with different interdisciplinary engineering concepts will produced better future path to extent.

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