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ROBOTS CONTROLLED BY BRAIN IMPULSES

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Abstract: In today's realities, progress is moving forward at incredible speed and things that just 10 years ago seemed like science fiction are now being used by people in real life or are under development. Now we can no longer imagine our life without some gadgets, such as smartphones or laptops. Moreover, many modern professions are based on modern technologies and a large number of people work on their further development, even the position of countries in the world largely depends on their technologies. One of these are robots that are controlled by impulses of the human brain, namely by the power of thought. We will talk about them in more detail in our article.

Keywords: brain–computer interfaces, robots, signals, artificial intelligence, electroencephalography (EEG), electrooculography (EOG), wearables.

Introduction. In order for robots to effectively carry out our instructions and meet our needs, it is imperative that they possess a deep understanding of human language and behavior. This often requires us to bridge the gap between our world and theirs by teaching them the complexities of our communication and providing them with precise and detailed commands for every task they are expected to perform. Only through this mutual understanding and cooperation can we ensure that robots function seamlessly and efficiently in our daily lives.

We took information about the concept of such technologies from the article "Engineeringand Engineeringand Technology History Wiki" [3]. Based on the article, below we talk about the operation of these technologies.

Main part. First Robotic Control from Human Brain Signals, in 1988, in the Laboratory of Intelligent Machines and Bioinformation Systems, human brain signals controlled the movement of a physical object (a robot) for the first time worldwide. This linked electroencephalogram (EEG) signals collected from a brain with robotics research, opening a new channel for communication between humans and machines. EEG-controlled devices (wheelchairs, exoskeletons, etc.) have benefitted numerous users and expanded technology's role in modern society.

It also expanded the EEG research and application with a new challenge of controlling physical objects, like opening doors, driving drones, driving wheelchairs, using EEG only. Medical applications with paraplegic patients are also part of this evolution branch.

Coupling brain–computer interfaces (BCIs) and robotic systems in the future can enable seamless personal assistant systems in everyday life, with the requests that can be performed in a discrete manner, using one's brain activity only.

Let's see how a wireless and wearable BCI device can control a quadruped robot—Boston Dynamics' Spot. The device measures the user's electroencephalography (EEG) and electrooculography (EOG) activity of the user from the electrodes embedded in the glasses' frame. The user responds to a series of questions with YES/NO answers by performing a brain-teaser activity of mental calculus. Each question–answer pair has a pre-configured set of actions for Spot. For instance, Spot was prompted to walk across a room, pick up an object, and retrieve it for the user.

As such, this project aims to pave a path towards future developments in modern day personal assistant robots powered by wireless and wearable BCI systems in everyday living conditions. EEG to this day remains one of the most practical and applicable non-invasive BCI methods because other imaging modalities such as functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), and positron emission tomography (PET) are expensive, technically demanding, and not easily portable.

A BCI system can be controlled using either endogenous (spontaneous) or exogenous (evoked) signals. In exogenous BCI, evoked signals appear when a person pays attention to an external stimulus such as a visual or auditory cue. The advantage of this approach includes minimalistic training as well as high bit rates up to 60 bits/min. However, the user needs to always attend to the stimuli, which limits its applicability in real-life conditions. Also, the user can become quickly tired when using exogenous BCIs. In endogenous BCIs, on the other hand, control signals are generated independently from any external stimulation and can be fully executed by the user on demand. It is also useful for those users who have sensory impairments while providing a more natural and intuitive means of interactions since users can spontaneously issue commands to the system.

Examples include motor imagery (MI). Motor imagery, however, is considered a complex, cognitively demanding task, and thus other mental strategies for BCI control are being actively explored, such as imagining music, phoneme imagery, visual imagery, mental rotation, mental calculations, and word association. There are many types of robots that robots controlled by "the power of thought": wheelchairs, exoskeletons, humanoid robots, arm robots and others. We found information about their use in articles "National Library of Medicine", "Science Direct" and shortly told about it below [1].

Wheelchair are used to help different people with any diseases, pathologies, and etc. Such an equipment can be operated with the help of a special EEG device. A person must fall into a state of complete concentration and imagine the movements of the wheelchair, after which it all turns into a code signal and the robot performs the corresponding actions like ride forward or back. In addition, such a device can be controlled using a mobile application. It can be used in conjunction with other works (for example, a robotic arm) to make life easier for people with serious illnesses.

Exoskeletons are used as devices to enhance physical performance of people for rehabilitation or assistance in movement. Now this technology is in development and cannot be used for normal daily movement. Epidural registers are implanted into the human brain. These signals are processed online using adaptive decoding to send commands to the exoskeleton.

Brain-controlled humanoid robots were explored as a potential solution for patients with LIS. Rossella Spataro**,** a clinical neurologist and brain-computer interface (BCI) researcher, reported on inviting four ALS patients and four healthy controls to use a humanoid robot with the aim of reaching and grasping a glass of water. Users were able to navigate the robot through an indoor maze to a target. They were presented with photos captured by the robot's perspective while traversing through stages of the maze. The users controlled its movements with left-hand, right-hand, or forward motor-imagery-based commands while wearing an EEG cap [4].

A robotic arm is a fairly common type of robot that helps people in different sphere of life. Collinger et al., in 2012, and Wodlinger et al., in 2015, reported performing two studies with the same female subject with tetraplegia who had two 96 channel intracortical electrode arrays implanted in her left motor cortex. Even people who have had a trauma with the central nervous system for a long time can control the prosthesis. Patients managed to guide the arm to drink coffee from a straw in a designated robotics workspace. To make BCI-controlled hand exoskeleton motor training solutions more accessible.

A modular pipeline for decoding human-intended goals from EEG signals was implemented using SSVEP + MI + EMG: What object to manipulate, decoded from SSVEP signals; How to interact with the object, decoded from MI signals; Where to interact, decoded from MI signals. A safety mechanism that captures muscle tension from jaw clench is used to confirm or reject decoding results.

As article "National Library of Medicine" said**,** there are also supporting infrastructures that facilitate a better connection between the work and the brain, for example Infrastructure of Ddog. This system contains numerous of different parts that help to connect people's mind with robots. It also uses artificial intelligence as a peripheral device that will help robots better perceive and execute commands. The goal of the system was to design an autonomous application that would enable a user to control a Spot robot based on the user's input via BCI and give feedback to the user and their caregiver using voice via the app [1].

Nowadays a team from MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) and Boston University are working on this problem, creating a feedback system that lets people correct robot mistakes instantly with nothing more than their brains. “Imagine being able to instantaneously tell a robot to do a certain action, without needing to type a command, push a button or even say a word” [2]. The author wanted to say that our lives can become much easier with the introduction of these technologies: effective completion of difficult tasks, improvement of the quality of medicine ant etc.

Past work in EEG-controlled robotics required training humans to “think” in a prescribed way that computers could recognize. It can be difficult because a person gets tired quickly.

“As you watch the robot, all you have to do is mentally agree or disagree with what it is doing,” approves Daniela Rus. “You don’t have to train yourself to think in a certain way — the machine adapts to you, and not the other way around.” [2].

They noted, that ErrP signals are extremely faint, which means that the system has to be fine-tuned enough to both classify the signal and incorporate it into the feedback loop for the human operator. In addition to monitoring the initial ErrPs, the team also sought to detect “secondary errors” that occur when the system doesn’t notice the human’s original correction [2].

CSAIL research scientist Stephanie Gil under the supervision of Rus, says that when robot misunderstands the task, it can cause a human reaction in order to get more precise instructions. While the system cannot recognize secondary errors in real time, Gil expects the model to be able to improve to upwards of 90 percent accuracy once it can [2].

As Andres F. Salazar-Gomez notes the system could even be useful for people who can’t communicate verbally: a task like spelling could be accomplished via a series of several discrete binary choices, which he likens to an advanced form of the blinking that allowed stroke victim Jean-Dominique Bauby to write his memoir “The Diving Bell and the Butterfly” [2].

Wolfram Burgard, a professor of computer science at the University of Freiburg who was not involved in the research said: “This work brings us closer to developing effective tools for brain-controlled robots and prostheses. Given how difficult it can be to translate human language into a meaningful signal for robots, work in this area could have a truly profound impact on the future of human-robot collaboration” [2].

Conclusion. The field of science is constantly advancing, and this is evident in the incredible progress that has been made in the development of modern robots. What once seemed like a futuristic concept has now become a reality, with robots being controlled directly by the human mind.

In our university, the study of artificial intelligence has become a specialized field dedicated to pushing the boundaries of technological innovation, as described in the article. This cutting-edge technology is playing a significant role in the evolution of modern robots and shaping the future of human-robot interactions.

Currently, brain impulse-controlled robots are primarily utilized for medical applications, showcasing the potential for revolutionizing healthcare practices. However, we envision a future where such advanced robots could seamlessly integrate into everyday life, offering unprecedented convenience and efficiency in various aspects of society. The possibilities for human-robot collaboration are endless, promising a future where technology and innovation continue to enhance the quality of life for individuals around the world.

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