OBSTACLE AVOIDING ROBOT WITH BRAIN INTERFACE

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Abstract

Obstacle Avoiding Robot with Brain Interface (OARBi) is a robot that can avoid obstacles and be controlled with our minds. It is a robot that will pave the way to future generations where humanity can control things with their mind with the additional security of the "thing" being able to automatically navigate through a determined path, if needed. The whole system, be it mind controlling or obstacle avoiding, is integrated onto a single robotic vehicle to demonstrate its capability of being controlled by the human mind and avoiding obstacles on its own. Although OARBi started off as a simple obstacle avoiding robot.
The aforementioned breakthrough in the BCI space was a BCI device, or EEG device to be exact, that could be used to read data from visual cortex part of the human brain and then process that data with machine learning and further continue to transport it to the digital computers so that it can be mapped to the onboard processor (which in this case, is an Arduino board) and in turn control the motoring functions of the robotic vehicle. Basically, OARBi has 2 integrated functions. OARBi can be controlled via our minds and OARBi can terminate its own (as part of obstacle detection). Furthermore, OARBi seamlessly integrates both mind-controlled and autonomous functions (Obstacle Avoidance), ensuring user safety by simultaneously navigating obstacles and responding to neural commands.

Keywords: EEG, OARBi, BCI, SSAO, SDK, CNN

1 Introduction

OARBi, or Obstacle Avoiding Robot with Brain Interface is not just a small scaled robot that can avoid obstacles and be controlled with our minds. It is a robot that will pave the way to future generations where humanity can control things with their mind with the additional security of the“thing” being able to automatically navigate through a determined path, if needed. The whole system, be it mind controlling or obstacle avoiding, is integrated onto a single robotic vehicle to demonstrate its capability of being controlled by the human mind and avoiding obstacles on its own. Although OARBi started off as a simple obstacle avoiding robot, a breakthrough in BCI or brain computer interface made the development of controlling via the brain and thus adding that to the already existing obstacle avoiding robot. The aforementioned breakthrough in the BCI space was a BCI device, or EEG device to be exact, that could be used to read data from visual cortex part of human brain and then process that data with machine learning and further continue to transport it to the digital computers so that it can be mapped to the onboard processor (which in this case, is anArduino board) and in turn control the motoring functions of the robotic vehicle. Basically, OARBi has 2 integrated functions. OARBi can be controlled via our minds and OARBi can move on its own. The additional feature is that both of these can be integrated together. As in, OARBi can be controlled via the mind and then even so, it can help avoid obstacles and even plan new routes and take appropriate measures to go through the appropriate route. The primary objective of OARBi extends beyond creating a robot solely controlled by the human mind. Instead, OARBi functions as a demonstrative platform with the potential for integration into practical applications. While OARBi may have limited standalone utility tailored to specific human needs, it stands as a compelling showcase of possibilities emerging from recent advancements in both the BCI and robotics realms.

2. Technologies Used

SOFTWARE AND HARDWARE ENVIRONMENT

Unity

Unity, a game engine created by Unity Technologies, debuted in 2005 at Apple's Worldwide Developers conference, initially for Mac computers. Over time, it expanded to encompass various platforms including desktops, mobile devices, virtual reality and consoles. The engine is especially favored for developing mobile games on iOS and Android, powering titles like Monument Valley, Call of Duty: Mobile, Cuphead and Beat Saber. Unity's reputation for user-friendliness makes it an attractive option for beginning game creators and is widely used in independent game development.

Unity caters to both 2D and 3D games and experience development. The engine utilizes C# as its main scripting language. This applies to both the Unity editor, where C# is used for creating plugins, and the games themselves. Notably, C# wasn't always the primary language. Previously, Unity supported Boo (removed in Unity5) and the custom JavaScript variant called the UnityScript (which was deprecated in Unity 2017). With rise of C#, these earlier options were phased out.
For 2D development, Unity offers sprite importing and a powerful 2D renderer. On the 3D side, it allows for granular control over textures, including mipmaps, compression and resolutions settings for each supported platform. Additionally, Unity provides advanced rendering features like Bump mapping, parallax mapping, reflection mapping, Screen Space Ambient Occlusion (SSAO) , dynamic shadows with shadow map, render-to-texture capabilities, and full-screen post - processing effects.

NextMind SDK

NextMind offers a Software Development Kit (SDK) specifically designed to streamline game and application development that leverages their brain-computer interface technology. This SDK provides a high-level interface, allowing creators to focus on their projects without getting bogged down in complex low-level details. Essentially, the NextMind SDK simplifies the process. The core functionality revolves around two key components: NeuroTags and a NeuroManager. NeuroTags mark objects within your application as "mind-controllable." The NeuroManager then bridges communication between these NeuroTags and the central NextMind engine.
Beyond these two core components, the NextMind SDK boasts a rich library of functions for application customization. Users can access sensor data like battery level and signal strength, manage Bluetooth scanning, and even simulate inputs. After designating NeuroTags, it's up to the developer to define the actions they trigger. The possibilities are vast, as NeuroTags can be linked to any digital or external output. The current version supports up to 10 simultaneous NeuroTags, with an expected increase in future releases. The SDK comes with two asset categories: Core Assets: These essential files are required to build a NextMind-compatible application. They include core libraries with main classes and helpful assets like prefabs, shaders, and development tools. Example Assets: These provide practical demonstrations of the SDK's usage, showcasing best practices like building custom calibration apps or tagging objects.

Arduino IDE

The Arduino IDE is a software application that runs on various operating systems (Windows, macOS, Linux) and is built using elements of C and C++. It serves as the primary tool for writing code and transferring those programs to Arduino boards. Beyond Arduino boards, the IDE can also work with compatible development boards from other vendors through the use of third-party add-ons.
Arduino IDE is a cross platform application which is suitable for Windows, macOS and Linux. It allows users to write code (in C/C++ with specific formatting) and upload programs to Arduino boards. The IDE leverages libraries providing common functions and utilizes the GNU toolchain for compilation. For uploading code, it employs Avrdude, a program that converts the code into a format compatible with the Arduino board's firmware. Notably, Avrdude serves as the default tool for uploading to official Arduino boards.
Arduino IDE originally stemmed from the Processing IDE. However, with version 2.0, it has transitioned to a new development framework. This framework leverages Eclipse Theia, which itself is based on Visual Studio Code.

Windows OS

Microsoft's Windows family encompasses various operating systems targeting different sectors. Debuting in 1985 as a graphical shell for MS-DOS, it captured the PC market with over 90% share, surpassing Apple's Mac OS. Though Apple contested Windows' GUI similarities to their Lisa and Macintosh, legal decisions favored Microsoft. While Android now dominates mobile devices, Windows maintains PC dominance and holds a strong share in server use. With ongoing innovation, Microsoft offers diverse Windows versions like Windows 10 for PCs and Windows Server for dedicated machines.

3. Related Works

[1] Controlling Wheelchair Using EEG Signal and Machine Learning

The research paper titled "Controlling Wheelchair Using EEG Signal and Machine Learning'' introduces a novel system that utilizes an EEG headset, specifically the Emotiv Epoc-X model equipped with 14-channel electrodes. This system aims to capture brain signals and employ machine learning techniques to enable wheelchair control via a Brain-Computer Interface. The algorithm is trained on a dataset comprising filtered brain signals corresponding to the subject's cognitive intentions, enabling it to predict their intended movements. Through testing conducted in a controlled environment, the classifier achieved an accuracy rate of 62.5%, underscoring the significance of accurate EEG signal recordings in ensuring dependable outcomes.

[2] Asynchronous Motor Imagery BCI and LiDAR-Based Shared Control System for Intuitive Wheelchair Navigation

The research paper "Asynchronous Motor Imagery BCI and LiDAR based Shared Control" explores a brain-controlled mobility system using real-time brain signals for navigation. This system incorporates "shared control," where environmental data from LiDAR sensors is continuously combined with EEG signals to enhance navigation accuracy. A study involving participants controlling a LiDAR and IMU-equipped wheelchair with either the brain-computer interface or a keyboard revealed that the shared control approach allowed participants who struggled with the brain-controlled system alone to successfully complete the task.

[3] EEG Based Smart Wheelchair For Disabled Persons Using Non-Invasive BCI

This paper describes a method that involves capturing EEG signals from the user's brain using a Brainsense Headset equipped with dry electrodes positioned on the forehead, facilitating the identification of artifact signals for wheelchair control. The EEG signals are processed through MATLAB and Arduino, enabling the generation of commands for wheelchair movement (forward, backward, left, right) based on the user's brain activity. This innovative approach harnesses non-invasive BCI technology to create a user-friendly interface tailored for individuals with disabilities, providing them with increased autonomy and enhancing their quality of life.

[4] Application of EEG Device and BCI for the Brain-controlled Automated Wheelchair

The study titled "Application of EEG Device and BCI for Brain-controlled Automated Wheelchair" explores the implementation of a brain-controlled robotic car. EEG signals were acquired using the Emotiv Epoc-X headset, equipped with 14 sensors positioned across various locations on the scalp. These raw EEG signals undergo processing to extract pertinent features, which are subsequently utilized in machine learning algorithms for classification. The resultant classifications are then employed to generate commands that control the vehicle in real-time.
This innovative system enables users to mainly interact with the robotic car by translating their brain activity signals into specific actions, such as turning, accelerating, or halting the vehicle. Such an approach offers a novel and intuitive method for individuals with disabilities to operate the car.

[5] Subject-Independent Brain–Computer Interfaces Based on Deep Convolutional Neural Networks

This paper proposes a subject-independent Brain Computer Interface(BCI) system using deep convolutional neural networks (CNNs). Unlike traditional BCIs that require calibration for each user, this system aims to eliminate that step by building a large database of the brain activity during motor imagery and leveraging CNNs. The core of the system involves a unique feature representation that combines traditional spectral-spatial features of EEG signals with those learned by the CNN. This combined approach aims to capture a wider range of discriminative brain patterns for improved BCI performance.

[6] EEG Based Smart Wheelchair For Disabled Persons Using Non-Invasive BCI

The IEEE research paper "EEG Based Smart Wheelchair For Disabled Persons Using Non-Invasive BCI" proposes a smart wheelchair system that integrates a non-invasive Brain Computer Interface(BCI) with automated navigation techniques to control the wheelchair in an indoor environment. The methodology of the research paper is not explicitly mentioned in the search results. However, the paper likely includes a description about experimental setup, the data collection, and analysis methods which are used for evaluating the overall performance of a specific proposed system. The paper may also include a discussion of the limitations and future directions of the research.

4. Proposed System

This research mainly proposes a specific system for mind-controlled robots, aiming to address limitations of existing solutions and ultimately achieve a fully functional robot with obstacle avoidance capabilities. The user-friendly system prioritizes reducing human effort by enabling intuitive control through brain-computer interfaces. This signifies a significant advancement as it empowers users to directly control robots with their minds.

* Minimum controlling methods required.
* Greater efficiency.
* Better control and safety.
* User friendliness, interactive and no hassle.
* Instantaneous thought processing

5. Objective

The OARBi project integrates two key objectives :

● Mind-controlled operation: OARBi can be controlled via the user's mind, utilizing EEG sensors to capture brain signals and translate them into input signals for the robotic vehicle.

● Autonomous navigation: OARBi is capable of moving on its own, using integrated sensors and algorithms to detect obstacles, plan new routes, and take appropriate measures to navigate through the environment.

Integration of mind control and autonomous features: OARBi can seamlessly integrate mind-controlled operation with autonomous navigation, allowing the user to control the vehicle with their mind while enabling the system to independently avoid obstacles and adjust its route as needed for user safety and convenience.

6. Methodology

Methodology system consists of :

1. Brain Signal Acquisition

Use EEG(Electroencephalography) - NextMind: This is the actual sensor used to get input from the visual cortex part of the brain (Fig. 1.1). The sensor has 9 electrodes in total and is positioned in the back side of the head in order for optimal contact points. The sensor then starts to collect the various signals produced inside the brain using the electrodes. It is then up to the various machine learning algorithms to determine the noise from the actual signals that is needed for processing. Sub components are mainly a NeuroTag which is basically a pattern that is recognized by the brain and the NeuroManager which processes the NeuroTag. When the brain senses the NeuroTag present in the display, it sends out a signal which is captured and realized by NextMind which in turn feeds it to the processors. The data is then transferred to the onboard computers via Bluetooth.

Fig 1.1 NEXTMIN EEG Sensor

2. Signal Processing

Arduino and the Bluetooth Module- Arduino is the onboard computer located in the actual build of OARBi. The Arduino receives the data from the sensor via the Bluetooth module. The Arduino is pre-programmed via the user to perform various actions according to the data received. The Arduino then transfers control to the motor driver.

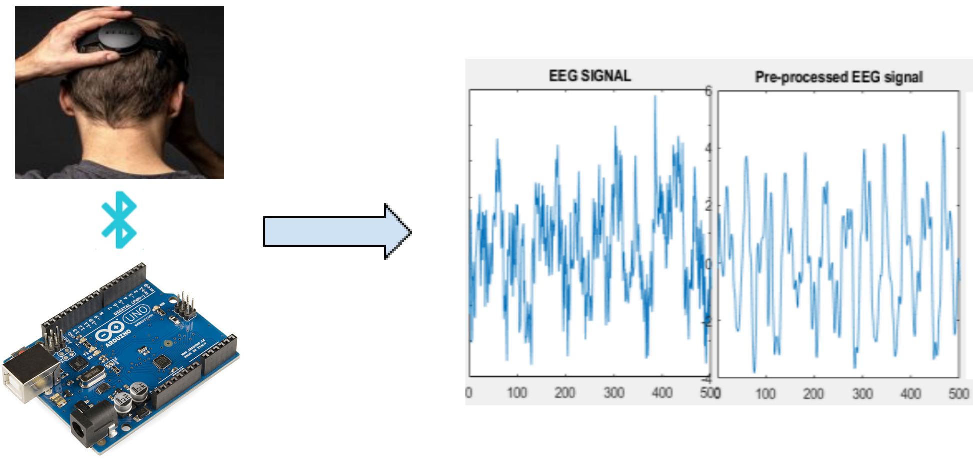

Fig 1.2 Arduino and the Bluetooth Module Signal Processing

3. Signal Feature Extraction

The motor driver- The motor driver receives the data from the Arduino and passes electronic signals to each individual motor Fig 1.3.

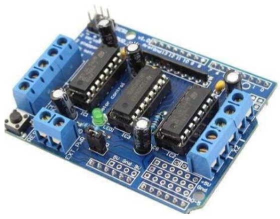

Fig 1.3 Motor Driver

4. Robot Hardware Integration

The ultrasonic distance sensor – The ultrasonic distance sensor is a special kind of sensor used to measure distance between OARBi and the obstacles in front of it by transmitting ultrasonic waves (Fig 1.4). The distance is measured by taking in account the time that is taken for the ultrasonic wave to be transferred and received by the sensor. If the distance is less than the specified distance in the program, OARBI stops on its own and plans a different course of route. This process continues in a repeated manner.

Fig 1.4 Ultrasonic sensor

7. System Architecture

The OARBi system architecture prioritizes modularity, scalability, and adaptability. It leverages three main modules: the mind-control module, the obstacle-avoidance module, and the driving module. These modules work in concert to allow the robot to navigate and circumvent obstacles using brain signals received from an EEG sensor and ultrasonic distance sensors for obstacle detection.The mind-control module is tasked with capturing user input from the brain and processing these signals to steer the robot's movements. The obstacle-avoidance module employs ultrasonic distance sensors to detect obstacles and determine the path to avoid them. The driving module governs the robot's movement based on motor signals obtained from the other two modules.

The hardware foundation of the OARBi system consists of an EEG sensor, motors, a motor driver, an Arduino microcontroller, a Bluetooth module, and an ultrasonic distance sensor. The EEG sensor captures signals from the user's brain. The motors are controlled by the Arduino microcontroller, which receives instructions from the mind-control and obstacle-avoidance modules via the Bluetooth module. The ultrasonic distance sensor aids the robot in detecting obstacles.

On the software side, the OARBi system necessitates a specific set of requirements for effective operation. The software is designed to run on Windows 7 (SP1+) and Windows 10 operating systems, with compatibility limited to 64-bit versions. The software stack incorporates Unity for creating interactive 3D content, the Arduino IDE for programming the microcontroller, and DirectX for enhanced graphics rendering. This software environment facilitates the integration of the mind-controlled functionality with the robot's autonomous navigation capabilities, offering a user-friendly interface for controlling OARBi's movements and interactions.

In essence, the OARBi system architecture represents a meticulously crafted fusion of hardware and software components that collaborate seamlessly to deliver a unique user experience. By harnessing cutting-edge technologies like EEG sensors and Bluetooth communication, the system fosters direct communication between the user's mind and the robotic vehicle. This architecture not only validates the technical feasibility of the project but also opens doors for future applications where mind-controlled robotics can be harnessed for various advantageous purposes, underscoring the innovative and forward-thinking character of the OARBi project.

8. Functional Requirements

Fig.1.5 explains about following step including :

● Signal Acquisition

Utilizes EEG to capture signals from the Visual Cortex of the brain using the sensor with 9 electrodes positioned at the back of the head for optimal contact points. If the attempt fails to sense the surroundings, the signals won’t be transferred to Nextmind.

● Signal Processing

After the signal is being processed and the unwanted noise will be avoided, The signal will be transferred to the arduino via bluetooth module. The arduino will then pass the control over to the Motor Driver. If it fails, Signal processing will continue with the unwanted noises, and the further transferring of the signals will get interrupted.

● Movements of Wheels

Use motors to move the wheels to propel and direct robot movement. If arduino fails to pass the signals to the motor driver. The robot will not be able to move further (It Stops).

● Obstacle Avoidance

Using ultrasonic distance sensors, the distance between robot and the obstacle is calculated and further movement will be estimated. If the Ultrasonic distance sensor fails, the sensor won't be able to calculate the distance between the obstacle and the robot. Therefore the robot will process the signal again to decide and finalize the direction.

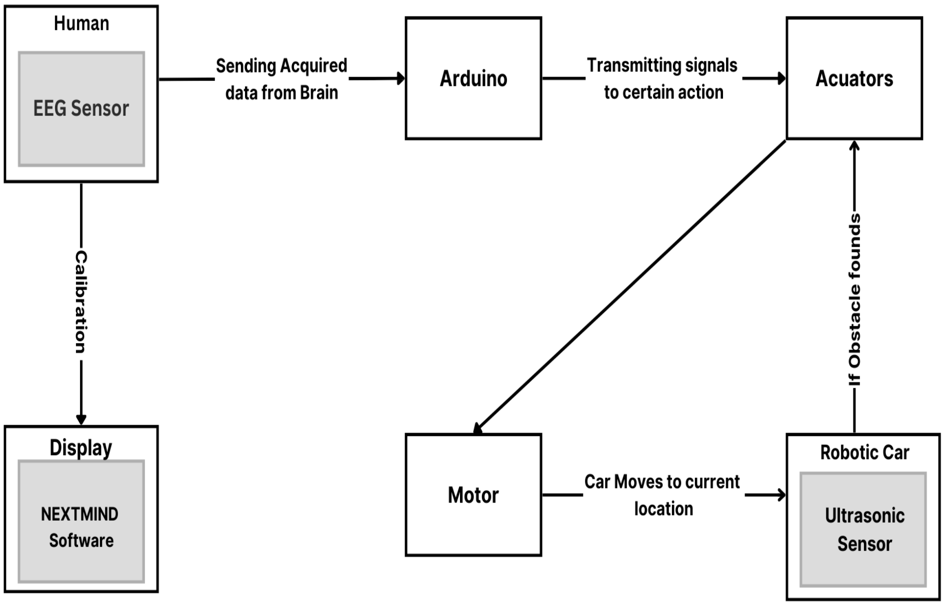

Fig 1.5 Functioning of the system

9. Non-Functional Requirements

Beyond outlining a system's functionalities, non-functional requirements (NFRs) delve into how the system should operate. These act as quality benchmarks, defining aspects like performance, reliability, security, user-friendliness, and maintainability. By addressing these "how" elements, developers ensure the system effectively meets user needs and delivers a positive user experience.
In the domain of EEG-based robotic control, a critical non-functional requirement is the implementation of robust cybersecurity measures to safeguard the Brain Computer Interface(BCI) system, ensuring the confidentiality and integrity of sensitive neural data.

10. Novelty

The novelty of the OARBi project resides in its pioneering approach to constructing a robotic vehicle capable of being maneuvered through the user's neural activity via a brain-computer interface (BCI), while concurrently integrating autonomous obstacle navigation functionality. This dual-control framework, wherein users can direct the robot using their cognitive impulses while the robot autonomously detects and circumvents obstacles, epitomizes a state-of-the-art amalgamation of sophisticated technologies. The project distinguishes itself through its focal point on seamlessly melding BCI technology with the robotic platform to enable cerebral command, thereby introducing a novel dimension to conventional robotic systems. By adeptly interpreting neural signals and translating them into executable directives for the robot, the OARBi project endeavors to realize dependable and prompt control, thereby ushering in fresh prospects for human-machine interaction. Moreover, the project underscores the development of a resilient obstacle avoidance mechanism, thereby enhancing its sophistication. Through the implementation of algorithms and sensor arrays capable of real-time obstacle detection and navigation, the OARBi project tackles critical safety and reliability concerns, ensuring seamless functionality across diverse environments. In essence, the OARBi project's uniqueness lies in its comprehensive endeavor to craft a mind-controlled robotic vehicle equipped with advanced obstacle avoidance capabilities, thereby pushing the boundaries of assistive technology and human-robot interaction.

11. Conclusion

In summary, OARBi, the Obstacle Avoiding Robot with Brain Interface, signifies a leap forward in robotics, blending state-of-the-art technology with inventive design to reshape human-robot interaction. Its intuitive controls, user-friendly interface, and advanced obstacle avoidance features render it accessible and indispensable across various user demographics. By seamlessly integrating mind-controlled and autonomous movement, OARBi provides a versatile and adaptable experience, addressing diverse user needs and environmental challenges. Beyond catering solely to tech enthusiasts, OARBi serves as a practical aid for daily tasks and offers invaluable support to individuals with physical limitations, expanding its potential user base significantly. Ultimately, OARBi epitomizes a future where technology seamlessly integrates into our lives, enriching our capabilities and fostering new opportunities for innovation and collaboration.

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