Using Brain-Computer Interface and Internet of Things to Improve Healthcare for Wheelchair Users

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***Abstract*—Brain-to-Thing Communication (BTC) is a type of ubiquitous system that aims to allow the communication from the human brain to smart objects in the Internet of Things (IoT). In this way, brain commands can be used to remotely control sensing and actuation of IoT devices. In this paper, we propose a BTC system for healthcare and show the viability to develop it. We present our BTC system architecture for wheelchair users, an illustrative application example, research challenges in this domain, and we show our current development status and perspectives.**

***Keywords*–Brain-to-Thing Communication; Internet of Things; Brain-computer Interface.**

I. Introduction

The Internet of Things (IoT) paradigm proposes the expansion of the current Internet infrastructure towards a network with smart objects connected to each other, which not only obtain environmental information, but also interact with the physical world using existing Internet patterns to provide information transparency services, analysis, applications and communications [1]. In this sense, IoT is not related only to interconnection of devices to the Internet, but also with (i) the knowledge acquisition from each smart object and from the physical word around it (i.e., sensing), and (ii) performing actions on the smart object (i.e., actuation).

On the other hand, the Brain-Computer Interface (BCI) technology has been proposed, which is a "communication system that does not depend on the brain's normal output pathways of peripheral nerves and muscles" [2]. A BCI system enables a human to interact with the surrounding environment through brain-generated signals (i.e., brain activity) obtained via ElectroEncephaloGraphy (EEG). BCI systems have normally been proposed to provide communication for people with some type of physical paralysis. Some BCI system examples are neural prostheses, robotic wheelchair [3], and robots in general.

From the union of IoT and BCI systems, we propose a Brain-to-Thing Communication (BTC) system for healthcare. The main idea is to enable a communication from the brain to smart objects (i.e., the "things") for wheelchair users. This will allow actuation and sensing to be performed on smart objects via commands sent by people from their controlled brain activity. In this way, the BTC system can contribute to improve quality of life and reduce intensive care costs for people with some physical or motor problem and who need to use a wheelchair (e.g., paraplegics, patients with severe diseases, such as Amyotrophic Lateral Sclerosis, or people who have suffered from a stroke), providing a mean to enable them to become more independent.

The rest of this paper is organized as follows. Section II presents the initial architecture of our proposed BTC system. Next, Section III exhibits a real illustrative example to show the usage of our proposed system. Section IV gives an overview of the challenges faced by this research. Finally, in Section V, we drive our conclusions.

II. System Architecture

Figure 1 illustrates the architecture of our proposed BTC system. Initially, signals are obtained in real-time via EEG and sent to the *Recognizer* component, which analyses and recognizes pre-defined patterns. These brain activity patterns represent mental states of the user (e.g., left hand or right hand imagined movements) and are recognized by signal-processing techniques [4]. A non-invasive EEG is a method to register brain activities with electrodes externally distributed along the head of the user. In cases in which it is required to identify only specific patterns (e.g., wink/blink, mouth bite, and muscle artefacts in general, such as hands movements and swallowing), only a few of electrodes are necessary to register signals, such as have been used by commercial and opened wearable devices (e.g., headsets, glasses, and caps as OpenBCI [5]). In this sense, that type of hardware is expected to be used for BTC systems, even if it is required to be adapted or embedded in a wheelchair.

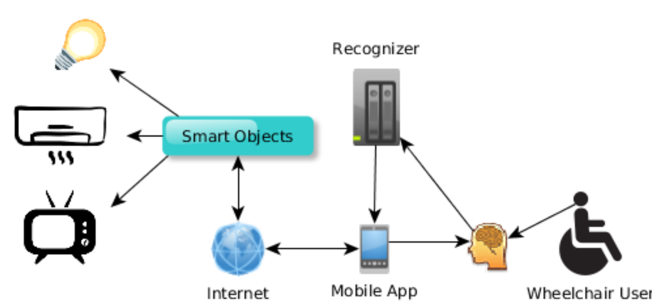

Figure 1. BTC System Architecture.

Recognized brain activity patterns are forwarded to the user's mobile device (e.g., smartphone, tablet) and used as input to an IoT mobile application, which can remotely communicate via Internet protocols with online smart objects, which are connected to the Internet via WiFi. By means of this communication, a brain activity pattern that is recognized by the *Recognizer* component can be used by the user to control smart objects. Therefore, BTC systems provide an alternative communication channel to perform actions and sensing in smart objects via commands sent by users from their controlled brain activities.

BTC Communication differs from IoT systems in general by providing a new communication channel for users, the brain. It differs from traditional BCI systems by proposing the following features:

- Smart environments: smart objects should be spread in the environment with embedded systems running sensing and actuation services (e.g., Raspberry PI [6], Arduino [7], and so on), providing smartness to the place where the wheelchair user lives (i.e., places where the user goes during his/her daily routine);
- Mobility: a wheelchair mobile user can continuously use the system anywhere and anytime, not only where he/she lives, but also during all his/her daily routine activities, remotely sending brain commands via a mobile application to smart objects;
- Transparency for the system: IoT and mobile applications do not know that user inputs are generated by recognized brain activities, because there is a component to recognize brain-generated commands;
- User-aware confirmations: brain commands sent to the mobile device must trigger visual, audio, or vibratory confirmations in the application to allow wheelchair users to know the brain activity patterns recognized by the system. This is specially important because, in some cases, the user may also have some communication problem (e.g., a blind, deaf, or mute person), requiring the user to know if the system correctly identified the command to be sent to a smart object;
- User-aware interfaces: mobile application interfaces should be adapted to allow an appropriate navigation. For example, the mobile application should have a few button options, limited to the number of brain activity patterns that can be recognized, providing a full mapping from all patterns to navigation options.

III. An Illustrative Example

Consider a person called Bob, a patient who lives most of the time in a wheelchair. At the same time, he would like to have a mechanism to control home appliances, because his wife works and thus he lives most of the day alone. By using a BTC system, Bob can turn on/off a lamp, an air conditioner, a television, a hot shower, or a residential security system in his smart home. Moreover, as the brain-to-thing communication is made through a home area network, if Bob is not physically located at his bedroom, he can also send brain commands to remotely control smart objects located there. For example, Bob can obtain the current state of the lamp located in his bedroom, use the mobile application to visualize this information, and act over the lamp, turning it on/off. Therefore, a BTC system is designed to provide resources for people with physical disabilities, mainly wheelchair users, and help them become more independent.

IV. Challenges

Some recent works in literature are going towards BTC systems by proposing initial solutions that show the technical viability to connect the brain with smart objects, such as [8] and [9]. Other recent proposals, such as [10] and [11], develop BTC applications for smart homes combining user inputs from the EEG with other devices (e.g., glass, mouse, keyboard). However, our solution mainly differs from all of them because it is focused on supporting wheelchair users, which have several limitations. This lies the novelty of our idea. In this sense, in addition to using real-time mobile network protocols to avoid delays in the communication among system components, our solution aims to address some non-trivial challenges in this domain:

- Real-time EEG signal processing: EEG signals should be processed and brain activity patterns recognized in real-rime by the *Recognizer* component;
- Good accuracy in recognizing brain activities: the *Recognizer* component should have a high success rate in identifying EEG signal patterns, in order to avoid mistakes. Of course, it is required that wheelchair users have knowledge about the system usage. For this, an initial training phase is needed. This phase is also required to calibrate the system;
- User-oriented mobile application: as previously explained in Section II, mobile application interfaces and confirmations should be developed considering the special needs of wheelchair users (e.g., physical movement and communication restrictions), which is a big challenge from the human-computer interface point of view.

V. Conclusion

We are currently developing the *Recognizer* component in Java. We decided to use this platform because of its rich development framework and wide acceptance. This implementation is integrating a commercial EEG in Brazil with Android mobile devices. The current version of the *Recognizer* component is identifying left and right hand imagined movements. We are also developing the mobile and IoT applications for Android OS and using a pub/sub communication middleware, the *Scalable Data Distribution Layer* (SDDL) [12]. In a second step, we intend to provide our solution regarding the ability of communicating with other people via a chat application. We will evaluate our solution considering as metric the accuracy in recognizing brain activities and also Human-computer interaction aspects, given that users may have different types of limitations. As future research efforts, we plan to develop a EEG wearable device in a cap format with additional resources, such as Global Positioning System and other embedded sensors.

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