Project 0:
NeuroRecovery App: An App for Post-Stroke Movement Restoration

Over twenty million people suffer from stroke annually world-wide and up to 40% of stroke survivors may suffer from permanent upper limb paralysis, which may significantly impact their quality of life and employability [1]. It has been clinically established that in conjunction with actual physical practice (PP), the motor imagery (MI) practice of goal-directed therapeutic motor tasks may significantly enhance upper limb recovery even for chronic stroke sufferers [2, 3]. Therefore, for movement restoration, there is a need for undertaking regular and highly focused motor exercises. Stroke sufferers often fail to perform appropriate therapeutic exercises because of several reasons. One of the main reasons is that people forget to do the exercises on a regular basis. This is further compounded due to lack of motivation in the absence of continuous observable recovery gain. They also find difficult to perform exercises appropriately without guidance from professional physiotherapists. However, access to physiotherapists is expensive and limited. Additionally if the exercises are performed with a physiotherapist's help, the patient may not apply his/her best effort in performing the therapeutic tasks resulting in passive practice and consequent inadequate neuroplasticity required for motor learning. In order to account for aforementioned issues and perform active motor exercises, it is required to develop an app that facilitates following activities:

- Scheduling of exercise sessions and issuing reminders;
- Displaying timing paradigm so as to perform repetitive exercises in a specified order and at desired frequency;
- Demonstrating the movement tasks through playing their videos;
- Recording of patient information, details of therapeutic tasks and periodic recovery outcomes;
- Providing neurofeedback in terms of changes in motor impairment.

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Project 1:
Developing a Self-driving Smart Wheelchair System

Under this project, a power wheelchair donated by InvaCare plc. is required to be made an autonomous system, so that even people with extreme movement disability could operate it independently. The chair is joystick operated and runs on a battery power supply located under the seating. The project aims to gain control of the chair using a flexible computing system rather than the joystick and build an appropriate command and control interface (CCI) to aid a disabled person in self-navigation. Keeping the mechanics of the chair unchanged, the project involves a CCI design and development that would help the user navigate through an office building or the home. Since there are varied disabilities, the design must appeal to the majority so that the market for the device is sustainable to pay for the manufacturing process and to allow for expansion.

In an ongoing work, a hardware interface consisting of analog and digital circuits has been designed to connect a tablet/palm PC (or PDA) to the driving mechanisms of the wheelchair. A software interface has also been created to issue operating commands through a mouse, an electronic pen or touch screen buttons. It is also possible to issue voice commands. Further work to be undertaken are:

- Test and make appropriate modifications for robust, jerk-free start-stop and smooth steering and operation of the wheelchair.

- Design of an appropriate GUI so that the wheelchair could be commanded through brain-waves or eye movement tracking.
- Design and develop an obstacle avoidance system incorporating appropriate sensors for object detection. This should automatically modify the motion trajectory in the presence of obstacles.

Project 2:
MEG experimental session booking and information management system

There is currently a challenging information management system type project requirement in the new magnetoencephalography (MEG) lab under the £5.3 M Northern Ireland Functional Brain Mapping (NI FBM) facility project at the Intelligent Systems Research Centre (ISRC). Under this unique facility (only one in whole of Ireland), brain scans are performed of the people referred from the hospitals right across the island of Ireland as well as of the healthy individuals volunteering to participate in advanced brain research. We need a robust MEG experimental session booking and information management system for this. The following are the main system requirements:

(1). Lab booking through internet;
(2). Billing for the scans;
(3). Facility for including a scan analysis report;
(4). Linking with patient data-base in NHS as well as health service in Ireland;
(5). Periodical report generation re lab utilisation.

There is a commercial supplier of a similar system at the following link. Please have a look at this link.
http://www.exprodo.com/

There are following other freely available systems:
https://www.roombookingsystem.co.uk/
https://www.yarooms.com/
http://classroombookings.com/ https://www.skedda.com/

Project 3:
Developing a Multi-modal Virtual Keyboard

Rationale

People with movement disabilities may have physical impairments that may substantially limit their ability for fine motor control. They may therefore not be able to type using a normal keyboard. These people may also find difficult to make use of other common computer input devices such as a mouse. Use of appropriate assistive technologies is essential for ensuring ICT accessibility to such people. There are a range of assistive devices currently available in the market. However, people suffering from severe movement disability such as motor neurone disease, cerebral palsy, spinal chord injury etc., may only be able to use an input device that can be operated through a single on-off switch activated by simple residual activities such as a single soft finger touch, eye movement tracking, breath or the brain signals from a brain-computer interface (BCI). Towards this end several types of virtual keyboard (VK) designs have been proposed in the assistive technology literature, [cf. 1, 2]. At the Intelligent Systems Research Centre (ISRC) we have also developed a simple VK which provides satisfactory performance and is in the process of being integrated with an EEG-based BCI for operation with thought alone [5, 6]. These VK designs are however often done in an *adhoc* manner and may not be fully integrated with the operating system to provide all the functionalities of a normal keyboard. There is therefore the need for devising a VK that is fully integrated with the operating system and is configured to provide optimal performance accounting for the specific disability of the user concerned possibly through a multi-modal user interface design.

Research Methodology

The VK design should allow selection of all the letters of alphabets and numbers at the fastest possible speed using simple commands. It would require displaying alphabets on the screen in an appropriate order to facilitate selection of a single letter at a time. It should also be possible to activate important special functions such as deleting a wrong selection and re-entering the correct letter etc. The project will therefore begin with the following tasks:

- Survey of existing VK designs and appropriate input devises currently available in the market.
- Review of requirements of the people with movement disabilities and relevant human computer interaction (HCI) issues.
- Review of accessibility guidelines [4].

Having gained deeper insight into the research problem through the above tasks and building on the current work at the ISRC [5, 6], the project will proceed on to developing an optimal architecture for the VK design. Its layout design will need to be optimised for enhanced multi-modal accessibility using specialized input devices: a soft-switch, an EMG Myo armband, an eye-tracker and brainwaves. The project will require performance evaluation of the VK taking into account all possible user errors [1, 2]. In order to have a universally operable system, a driver/application program interface (API) will also need to be created.

Anticipated outcomes

It is anticipated that the project will result into a commercial virtual keyboard that enables highly disabled people to interact flexibly and efficiently with ICT systems.

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Project 4:

Designing Web-sites with Multi-Modal Accessibility for People with Movement Disability

Rationale

In the current high tech age, internet browsing has become an integral part of day-to-day life in every sphere of human activity. As many people take this for granted, people with disabilities face lots of difficulty in accessing the internet. For example, the UK has over 3.4 million people with disabilities preventing them from easily using a standard keyboard, screen and mouse set-up [1]. In particular, the people with movement disabilities may have physical impairments that may substantially limit their ability for fine motor control. They may therefore not be able to type and interact using a normal keyboard and a mouse. These people may also find difficult to make use of other common computer input devices. Use of appropriate assistive technologies is essential for ensuring accessibility to such people. There are a range of assistive devices currently available in the market. However, people with severe movement disability may only be able to use an input device that can be operated through a single on-off switch activated by simple residual activities such as single soft finger touch, eye movement tracking, breath or the brain signals from a brain-computer interface (BCI) [4]. This project aims to devise a web-site design strategy that makes internet accessible to people even with severe movement disability.

Research Methodology

To accomplish the above aim, this project will begin with the following tasks:

- Review of bowser designs facilitating flexible multimodal accessibility [5, 6].
- Review of requirements of the people with movement disabilities and relevant human computer interaction (HCI) issues.
- Review of web content accessibility guidelines [3].

Having gained deeper insight into the research problem through the above tasks, the project will proceed on to developing a novel strategy for the web-site design for enhanced multi-modal accessibility using specialised input devices such as a soft-switch, a BCI device or an eye-tracker. The efficacy of the strategy will then be evaluated by developing a prototype web-site for the BCI and assistive technology research team.

Anticipated outcomes

It is anticipated that the project may result into setting a guideline for designing a web-site with enhanced accessibility. More importantly a novel web-site design strategy will be developed that will ensure better accessibility for people with movement disability.

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Project 5:
Self-adaptive Feature Classification for a Practical Brain-Computer Interface

Rationale

Electroencephalogram (EEG) and other electrophysiological measures that reflect brain function can support non-muscular pathways for communication and control, commonly called brain-computer interfaces (BCIs). These are especially useful for those who are paralysed or have severe motor disabilities, such as people suffering from motor neurone diseases (MNDs) and spinal cord injury (SCI) [5][6]. A conservative estimate is that 1 in 3500 of the world population may suffer from a neuromuscular disorder [7]. Beyond medical applications, a practical BCI offers an additional and independent communication channel to healthy users using brain activities alone, which has a range of promising applications such as computer games with intuitive control strategies [8] and advanced virtual reality (VR) scenarios [4].

Due to severe non-linearities and non-stationarities in brainwaves characteristics obtained from EEG signal, the current EEG-based BCI systems suffer from limited accuracy, are insufficiently robust for regular and sustainable use and are too expensive to maintain. At ISRC, we have developed promising algorithms for EEG signal pre-processing, feature extraction, and feature classification providing significant improvement in BCI performance [1][2][3][11] [12]. Building on these promising works, this project aims to investigate how non-stationarities in EEG signal characteristics can be effectively accounted for in an automated way, so that a more practical BCI system could be developed.

Research Methodology

To accomplish the above aim, this project proposes to investigate artificial intelligence (AI) techniques that can effectively account for nonlinearities and non-stationarities in brainwaves characteristics making enhanced utilisation of EEG data obtained from subject training on motor-imagery related cognitive tasks. Several promising AI techniques such as evolving fuzzy neural networks (EFNNs) [9], self-organising fuzzy neural networks (SOFNNs) [10], and ensemble learning [12] have been reported for on-line modelling of non-stationary systems. To start with the project will involve a deeper study and a critical analysis of these techniques with the purpose of applying them for devising a self-adaptive feature classification scheme. The most appropriate technique will then be selected and used to devise a self-adaptive feature classifier. The newly devised classifier will be applied in the existing BCI system and a comparative performance evaluation will be made to ascertain the efficacy of the self-adaptive classifier.

Anticipated outcomes

It is anticipated that a successful completion of the project will result into a practical and reliable BCI that can be used on a regular basis both by the disabled and healthy users.

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Project 6:

Developing an Intelligent Assistive Robotic System using a Drone

UK has 3.4 million people with disabilities preventing them from easily using a standard keyboard, screen and mouse set-up [2]. A significant proportion of disabled people may be suffering from tetraplegia. This means that they cannot move from the waist down. Robotic assistants hold great promise in helping individuals with disability lead more fulfilling and independent life. This project aims to investigate how modern telepresence robots can help these people regain some of their independence [1, 4]. To this end, it is required to investigate and develop an advanced assistive system with following features:

- A highly user friendly and interactive graphical user interface (GUI) for bidirectional interaction with a drone (Parrot AR Drone 2.0 elite) using simple input devices such as on/off soft-switch, a BCI device or an eye-tracker operable by severely disabled persons.
- A software system that allows the drone to act as an avatar of the user and facilitates stable control and navigation by the user even with extreme physical disabilities.

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Project 7:
Applying Artificial Intelligence (AI) technology for decoding of cognitive tasks from neuroimaging data

Artificial Intelligence (AI) may be considered one of the largest technology revolutions with the potential to disrupt virtually every aspect of human existence. Andrew Ng, Co-founder of Coursera, compares the transformational impact of AI to that of electricity 100 years back. It basically involves a bunch of technologies that help machines act with higher level of intelligence in terms of emulating human beings in sensing, comprehending, and acting. In practical terms, AI value chain involves some or all of the following activities: data capture, cleansing of raw data, labelling & standardisation, annotation of raw data, creation of machine learning (ML) models, training of ML models with annotated data, testing of models on new data and development of solutions. Although all these activities are crucially important, the ML algorithms are often given prominence, as through these AI systems gain ability to learn without explicitly being programmed. Basically using ML algorithms such as a deep learning neural network (DLN), a machine gets trained using large quantity of data and in turn gains the capability to perform specific tasks.

In this project, to start with, the student will be required to research thoroughly all the activities of the AI value chain. He/she will then apply most appropriate AI techniques for analysing a neuroimaging data-set recorded in the magnetoencephalography (MEG) scanner of our NI Functional Brain Mapping (NIFBM) facility located at ISRC. The MEG scanner involves acquisition of brain responses from a large number of channels (i.e. 360 for Elekta Neuromag Triux system). The MEG dataset includes recordings from fifteen healthy participants for two experimental sessions performed on two different days [1]. The dataset was recorded when participants were performing 4 different mental imagery tasks, namely both hand movement, both feet movement, subtraction, and word generation. It is required to undertake the temporal decoding of the above cognitive tasks so as to achieve highest possible decoding accuracy. Such a decoder is critically and urgently required for devising a practical brain-machine interface [1, 2] as well as studying cognitive processing in the brain [3].

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Project 8:
A COVID-19 App

An effective App serving the challenging needs of the people during COVID-19 pandemic will be a very timely and useful project work. Although there are quite a few apps available in the market, there are a range of possibilities for developing an advanced COVID-19 App as listed below.

- Present the most relevant information about the evolution of the disease through interactive graphs. It should aim to create scientifically accurate plots about the evolution of the COVID-19 according to the data provided daily by reliable sources such as Center for Systems Science and Engineering (CSSE) at Johns Hopkins University JHU).
- One can improve the graphical user interface (GUI) and make it highly interactive and self-explanatory, so that there is no need for a professional (medical or otherwise) to advise when to approach for COVID test and where to go and get a test done.
- The app should keep track of the infections in the local area.
- It should track the movements of the user and trace those people who have come in close contact and inform them, if the user has got infected.
- It should keep up-to-date with the new research findings reported globally.
- Make it usable on any platform apple, windows, or android.

Project 9:
Open Project Topics

I very much welcome new project topic suggestions. I am particularly interested in projects in the areas of artificial intelligence (AI), machine learning, data engineering, data validation and visualisation, brain modelling, brain-computer interfaces and neuro-rehabilitation, assistive technology and biometrics. Project topics in connection with fitness app, mobile attendance monitoring, and appointment booking system are also welcome. More details regarding my research interests and publications are available at: https://pure.ulster.ac.uk/en/persons/girijesh-prasad.