Harnessing brain power at NUI Maynooth

Optical BCI as developed by PhD student Shirley Coyle.

The Department of Electronic Engineering at NUI Maynooth is involved in exciting interdisciplinary work in the biomedical, digital signal processing, control and electronic systems areas. Here Tomas Ward, Seán McLoone and Shirley Coyle highlight three specific projects.

Researchers at the Electronic Engineering Department at NUI Maynooth have developed the world's first optical brain-computer interface (BCI), which uses reflected light to determine patterns of brain activity. A BCI is a device that allows users to interact with a computer and, ultimately, their external environment through thought alone. Such systems offer augmentative communication possibilities for people with severe disability. While BCIs already exist, they almost universally rely on electrical measurements of brain activity (termed an electroencephalogram or EEG) as recorded through electrodes applied on the scalp. Such systems are very difficult for users to master and, consequently, are rarely used outside research laboratories. Recognising this weakness, researchers at NUI Maynooth embarked on building a BCI that harnessed a totally different means of measuring brain activity.

The optical BCI detects characteristic changes in the cerebral haemodynamic responses that occur during motor imagery tasks. Mental tasks involving motor imagery are well established protocols for controlling some of the traditional EEG-based BCIs. On detection of features of the optical response, resulting from localised haemodynamic changes, the BCI translates such responses and provides visual feedback to the user. To extract these features of the optical response, the system implements some straightforward signal-processing, allowing adequate accuracy and information transfer rates.

Compression for distributed interactive media

Many engineers may not be acquainted with the term distributed interactive media, but it is the most accurate description of the networked computer game. Multiplayer online gaming is one of the fastest growing sectors in the entertainment and media industries with millions of users daily logging on to compete or in some cases cooperate with others in virtual persistent worlds. However, achieving the shared sense of space, interaction, time and experience for geographically separate users over an unreliable internet is a difficult task, considering the finite speed at which information can be transmitted across any medium. To solve this problem, Maynooth researchers are using sophisticated models of user behaviour, which are distributed and updated during the session so that each client (user) can interpolate the media stream in the absence of constant updates. This ultimately makes distributed interaction media more robust for real-world usage and allows scalability well beyond current methodologies. While this work may seem quite removed from biomedical engineering, the initial research seed was inspired by problems recognised in telemedicine and remote surgery. In such applications, procedures carried out remotely can be entirely disrupted by the vagaries of network performance.

Computational intelligence

Computational intelligence (CI) refers to learning and optimisation methods inspired by scientists' and engineers' attempts to model and replicate various aspects of human intelligence, evolutionary processes and emergent behaviour in nature.

The principle learning methodologies are artificial neural networks (ANNs) and fuzzy logic systems (FLSs). ANNs are mathematical models of the human brain, attempting to reproduce its computational, adaptation and learning capabilities, while FLSs are models attempting to replicate the brain's ability to represent and reason with imprecise knowledge and data. For example, we identify the temperature of water in a bath as hot or cold, rather than precise values such 10^{O}C or 40^{O}C. Using appropriate training algorithms and data, these models can learn to replicate the behaviour of complex systems and adapt to changes as they occur. They have been successfully applied in such diverse problems as medical diagnosis, machine vision, time series analysis (e.g. sonar and radar), economic forecasting, mortgage risk assessment, odour sensing, wine tasting, stock market prediction and avalanche forecasting. Nature inspired optimisation methodologies include algorithms informed by genetic or evolutionary processes; the movement and interactions of swarms of insects, flocks of bird, schools of fish and so on; artificial immune systems processes; and ant and bacteria colony optimisation.

In contrast to conventional optimisation methods, these techniques are capable of performing global optimisation of high dimensional problems with ill-defined multi-model and multi-objective cost functions.

The control systems group at NUI Maynooth is exploring the use of combinations of these innovative techniques to model, control and optimise industrial and environmental processes. In addition, interdisciplinary researchers are looking at incorporating CI concepts into multi-player/multi-agent distributed computer games and microelectronic circuit design and test. In gaming environments, the objective is to improve the quality of play by modelling and anticipating the actions of human controlled agents and adding intelligent behaviour to artificial agent so that they continually adapt to and learn from opponents' tactics. CI is also being considered in the field of microelectronics as a means for optimising the design and testing of next generation Wi-Fi components. This particular research is contributing to the activities of the electronic systems research group at NUI Maynooth, a group focusing on the design and implementation of novel system architectures for integrated circuits, primarily for the wireless communications application space (Wi-Fi, Wi-Max and mobile communications). As with the previous two examples, this research relies on a large interdisciplinary team of engineers, scientists and mathematicians for its success ■

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