Pioneering neural implant work at the University of Reading, UK

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INTRODUCTION

The Cybernetics Intelligence Research Group (CIRG) at the University of Reading, UK, is made up of seven full-time academics plus various research assistants and PhD students. We broadly define *cybernetic intelligence* as the study of intelligence and its applications. Members of CIRG are internationally active in the following areas: embodied machine intelligence (for example, learning mobile robots), neural networks (novel types, their properties and applications), intelligent search (stochastic diffusion, genetic algorithms), intelligent control (including novel optimal control, non-linear control and modelling techniques), applied cognitive systems (including pattern classification and learning classifiers), neuroscience (models of information processing in the brain), and neural implant technology.

The group has witnessed considerable success in the field of autonomous intelligent robotics. In collaboration with the bioengineering unit of the Interactive Systems Research Group at the University of Reading, pioneering research has been undertaken into human-computer implant technology, utilising a radical new direct interface to the nervous system. The group's research on intelligent search methods and optimal control is currently being applied in interplanetary mission design, with funding from the European Space Agency.

In the mobile autonomous devices laboratory (MADLAB), some of the group's main applications are developed and tested. For example, this lab has been responsible for developing the seven dwarf learning robots, the robot kit Cybot (in collaboration with Eaglemoss Publications), and the London Science Museum robotics exhibit.

In the academic year 2002-2003, the group received over £900,000 in research funds from UK research councils, the European Union, industrial organisations, charities, and the Department of Trade and Industry.

Further information about the group can be found through its Web pages: http://www.cirg.reading.ac.uk/

This article describes a current project dealing with the assessment of invasive neural implant technology, lead by Prof. Kevin Warwick in collaboration with Mark Gasson and Adam Spiers, who are all members of CIRG. The project, which is taking place between August 2004 and August 2005, is funded by Institut International de Recherche en Paraplégie (IRP, Switzerland), and is worth c. US$170,000.

MOTIVATION FOR THIS WORK[1]

Humans typically use physical means, such as a keyboard, to interface with computers in order to perform operations of data processing, calculation and mass storage far beyond the capabilities of a conventional human.

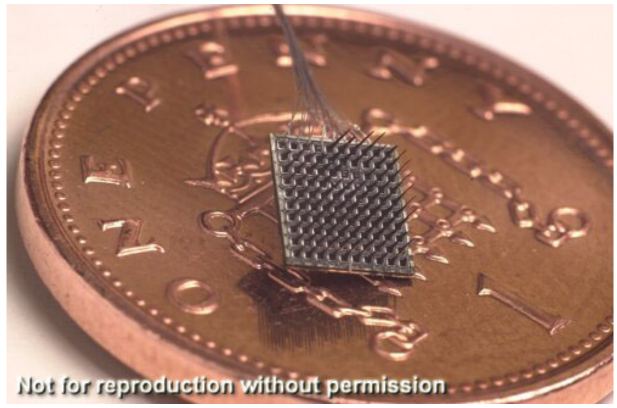

Figure 1: The picture shows a neural implant that was surgically inserted in the median nerve at the wrist of the left arm of Prof. Kevin Warwick, as part of a previous project.

Alternative enhancements in the form of voice synthesis, electronic prosthetic limbs and environmental controls all seek to restore functionality and improve quality of life for individuals with bodily impairments.

Unfortunately, many of those most likely to appreciate such assistive technology also have the greatest trouble in establishing a relationship of control with the equipment.

ALS, also known as Lou Greigs disease, is one of a number of degenerative motor neuron diseases that leaves the patient with full cognitive activity but without the ability to move or speak. The patient is referred to as 'locked-in' and often able to communicate by responding to questions with yes/no eye blinks. If thirsty the patient must *wait* to be asked whether he wants a drink.

By blinking 'yes' in response to the letters of the alphabet, recited by a nurse, a former journalist managed to write his memoirs one letter at a time [1]. Such an achievement demonstrates that though physically incapacitated the individual can be mentally acute.

It is no doubt that expanding communication beyond eye blinks would increase quality of life significantly. Yet with carer's time (and perhaps patience) limited, one must look to alternative methods of interpreting a patient's wishes.

Invasive implant technology seeks to provide this alternative interface by measuring voluntary signals directly from within the human nervous system, eradicating the need to manipulate external devices in order to interact with technology.

In previous work carried out at the University of Reading, a 100-pin microelectrode array, which is shown in Figure 1, was inserted in the median (arm) nerve of a healthy human subject [2]. Once in place, the array demonstrated principles of quantifiable measurement and stimulation of the peripheral nervous system. Since that time, attention has turned to the more information-rich signals present in the brain.

By targeting the brain directly, it is possible to monitor the activity of neurons and correlate this data to events such as speech, stimulus response, memory recall and motor functions.

[1] Section contributed by Adam Spiers.

Arguably the most quantifiable area of the human brain is the motor cortex. Ordered into well defined sections, electrical activity (from neuronal firing) increases significantly in relevant areas following the intention of movement.

Non-invasive measurement techniques have been used extensively to identify neuronal chatter within the brains of humans and animals [3]. Methods either rely on large expensive machinery (fMRI) or surface electrodes requiring expert placement (EEG). Though the latter is more practical, it suffers from signal degradation/distribution consequent to passage through layers of cranial tissue. Resulting signals represent the massed activity of large groups of neurons.

With appropriate levels of signal processing and EEG measurements, it has been possible to create a switch via comparative neuronal activity analysis of a few large and generalised cortical regions [3, 4]. Such single switches can be used to great effect by patients for typing via simple cursor control.

Moving the measurement locale to within the brain allows focus on individual neurons. Instead of generalised signals, one may instead expect high dimensional and specific responses to subtle details such as individual finger movements. Interfacing at such proportions permits control considerations of the most complex of assistive technologies.

Applying small electrical signals to such close proximity electrode channels theoretically enables stimulation of neurons to create environmental feedback (i.e. virtual touch) within the patients mind.

The established plasticity of the human brain suggests that such closed-loop bi-directional control would eventually result in assimilation of a neural prosthesis into the body/mind representation of the subject. Such principles have already been demonstrated with implanted rats and monkeys controlling external actuators [5], and paralysed humans establishing simple, albeit slow, cursor control [6].

Though the usefulness of such technology is undeniable, the concept of human brain implantation is one that causes social unease. There exists an immense number of associated medical and ethical issues combined with the common knowledge that the human nervous system is incredibly complicated, mysterious and fragile.

To justify the necessary high-risk and traumatic surgery, it must be necessary to establish a high degree of confidence prior to implant insertion, especially considering the greatly impractical correction procedures that may be required should anything go wrong with the implant.

It is the goal of current research at the University of Reading to produce a definitive technology reference to allow future researchers to make informed decisions when planning invasive brain-machine interfacing.

Via in-vitro testing a diverse range of implantable devices will be analysed in order to produce their electrical and mechanical characteristics, thus minimising any technical surprises that could otherwise impair future surgical procedures. By bypassing a large degree of hardware determination, investigators should be able to divert their resources into more cumulative results.

THE PROJECT[2]

This projects aims to carry out the preliminary work necessary to prepare a future implantation experiment. The main stages of the project are:

(a) Conduction of a literature survey into the current state of the art of implantable devices and achieved / predicted applications of these devices.

(b) Acquisition of a variety of devices deemed to have potential for useful implantation in a human brain.

(c) Vigorous testing of acquired devices to determine suitability for chronic implantation.

(d) Example characteristics include:

- Maximum current that may be passed though device before failure.
- Electrode impedance changes following exposure to cranial tissue (Bio-degradation).
- Thermodynamic effects of electrode stimulation on nearby tissue.
- Gassing effects of electrode stimulation on nearby tissue.
- Harmonic distortion analysis.
- Mechanical properties: permitting stable adhesion to implant site while minimising chance of tissue damage.

(e) Compilation of results into a format that may be easily referenced, thus permitting future researchers to focus their resources on implantation experiments while eliminating a large portion of potential hardware 'surprises'.

It is hoped that experiments will begin in January 2005.

CONCLUSIONS

This short article has introduced the work of the Cybernetics Intelligence Research Group at the University of Reading, United Kingdom, and it has described current work on the assessment of invasive neural implant technology. For chronically paralysed (locked-in) individuals, communication exists only as yes/no eye-blinks. By harnessing voluntary brain signals and using them to control external devices such as computer mice / robot actuators, these individuals will be given a much higher quality of life. This projects aims to carry out the preliminary work necessary to prepare future implantation experiments.

[2] Section contributed by Adam Spiers

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REFERENCES

1. Jean-Dominique Bauby (1997), "The Diving Bell and the Butterfly: a memoir of Life in Death", Vintage publishing.

2. Warwick, K., Gasson, M., Hutt, B., Goodhew, I., Kyberd, P., Andrews, B, Teddy, P and Shad. A (2003), "The Application of Implant Technology for Cybernetic Systems", *Archives of Neurology,* Vol. 60, No. 10, pp. 1369-1373.

3. Donoghue, J.P (2002), "Connecting Cortex to Machines: recent advances in Brain Interfaces", *Nature Neuroscience,* Vol. 5 Supplement, November 2002, pp 1085-88

4. Scherer, R.; Muller, G.R.; Neuper, C.; Graimann, B.; Pfurtscheller, G. (2004) "An asynchronously controlled EEG-based Virtual keyboard improvement of the spelling rate", *IEEE Transactions on Biomedical Engineering*, Vol. 51, pp. 979-984

5. Chapin, J. K., Moxon, K. A., Markowitz, R. S., Nicolelis, M. A. (1999) "Real-time control of a robot arm using simultaneously recorded neurons in the motor cortex', *Nature Neuroscience,* Vol. 2, pp. 664-70.

6. Kennedy, P., Bakay, R., Moore, M., Adams, K., Goldwaith, J. (2000), "Direct control of a computer from the human central nervous system", *IEEE Transactions on Rehabilitation Engineering*, Vol. 8, pp. 198-202.