DEVELOPING A HUMAN-LIKE ROBOT ARM

by Johan and Tania Hanekom

To come to the aid of amputees and paraplegics by developing an artificial arm that moves naturally and is able to lift objects of different sizes, shapes and fragility. That was the challenge set to students from the Department of Electrical, Electronic and Computer Engineering in the University of Pretoria's School of Engineering.

Incredible advances in upper extremity prosthetics and robotics research have taken place over the past few years. These include the vast improvements that have come about with regard to the capabilities of artificial limbs. Some of the drawbacks that remain, include the inability to lift objects of different sizes, shapes and fragility and the fact that the movements produced by these limbs still appear unnatural. The ultimate aim, however, is to develop a human-like robot arm that will make it possible for individuals with a prosthesis to function as effectively as they did before losing a limb.

Over the past few years, a number of students from the University of Pretoria, under the guidance of Prof. Johan and Prof. Tania Hanekom of the Bioengineering Group (associated with the University's Department of Electrical, Electronic and Computer Engineering) have been working on various aspects of electromyographically (EMG) controlled robotic prostheses in order to address these challenges.

Initially, the projects made use of an old cyber robot arm. In 2005, however, Mr Marius Vermeulen was tasked with developing a replacement. For his final-year project, Vermeulen set out to develop a robot arm that would resemble its human counterpart in size, shape, functionality and degrees of freedom, and that could be used in upper extremity prosthetics research.

Vermeulen's design enabled the prototype to lift objects of various sizes, shapes and fragility, without prior knowledge of these objects. The robot arm consists of shoulder, elbow, wrist and finger joints, which are all driven by stepper motors. He designed the electronics that drive the arm to be easily adaptable to both computer and EMG control, and also manufactured the arm himself – a huge accomplishment given the complexity of the mechanical design.

In 2006, another student, Mr Gerhard Mostert, continued with the design and implementation of an EMG control system for the robot arm. EMG signals are electrical signals caused by muscle activity. The objective of the EMG control system is to provide an interface for individuals who have lost a limb through amputation by granting them the ability to control the prosthetic robot arm.

There are a number of challenges to using EMG signals to control a system such as the robot arm. EMG signals are very small and are frequently masked by environmental noise. A special design and signal processing techniques are therefore required to extract the EMG signals from the noise. Another problem is the presence of crosstalk signals. This involves the detection of the electrical activity of neighbouring muscles when the activity of a specific muscle has to be recorded. These signals have to be recognised and rejected in order to extract the correct control signals from the EMG. The adaptability of the system to different users is another issue that needs to be addressed. The muscle size and shape, skin conductivity and thickness of the subdural fat layer of individuals vary, which affects the EMG readings. The design of both the hardware and software of the robot arm need to take these variations into consideration.

To address these challenges, an EMG control system uses electrodes to detect the voluntary muscle contractions produced by the user. Biopotential amplifiers are then used to amplify the minute EMG signals to levels that can be digitised for further processing. A number of filters remove unwanted noise from the signal, while a signal-processing algorithm derives control signals from the EMG input.

→ *Displaying the functioning of the robot arm are (from left to right): Mr Marius Vermeulen, Prof. Johan Hanekom (Head: Bioengineering Group, University of Pretoria), Prof. Tania Hanekom (project supervisor) and Mr Gerhard Mostert.*

The control signals are subsequently used to drive the robot arm through its control electronics circuitry.

The robot arm is a valuable research tool to test the effectiveness of various EMG control algorithms. The work of the Bioengineering Group will therefore continue in its efforts to design and implement a wearable robot arm that can be controlled by the residual functional muscles of amputees, as well as a robot arm that can be controlled by the functioning muscles of paraplegics or quadriplegics.

__Prof. Johan and Prof. Tania Hanekom__ are both associated with the University of Pretoria's Department of Electrical, Electronic and Computer Engineering. Johan is Head of the Bioengineering Group.

For more information on the work of this research group, contact Prof. Johan Hanekom at johan.hanekom@up.ac.za or Prof. Tania Hanekom at tania.hanekom@up.ac.za or go to www.ee.up.ac.za.