Progressive Prosthetics

The problem we are working on is that of natural control of prosthetic hands. This is for people who have lost their hand or were born without it.

Current prosthetic hands have very advanced hardware, but they are difficult to control, and they don’t give any feeling back to the user, so they feel unnatural.

Our approach is to use a computer model as a link between the user and the prosthesis. The model can predict the natural movements of the missing hand from signals we can record from remaining muscles, and then send these movement instructions to the prosthetic hand.

At the same time, the computer model can generate proprioceptive information, which is what gives us the sense of where our hand is in space without looking at it. So it can provide feedback that is currently missing from prosthetic hands.

Using our computer model we hope to make prosthetic hands move and feel more like real human hands.

Connecting the prosthetic hand to the nervous system

KS4 Curriculum links

Biology: Coordination and control

- principles of nervous coordination and control in humans
- the relationship between the structure and function of the human nervous system
- the relationship between structure and function in a reflex arc

How do we control our own hands?

We have more than thirty muscles to control our hand movements. Most of the muscles are located in the forearm, with tendons that attach them to the bones of the fingers and thumb.

What is the benefit of having most of the muscle bulk in the forearm?

When we want to move, the brain sends electrical impulses down the nerves to the appropriate muscles. At the same time, sensory information such as touch and temperature is sent back to the brain from the hand.

AT THE EXHIBITION:

We will have physical models of the human hand, so you can explore the muscles involved in hand control. We will also have a few prosthetic attachments that are not hands… See if you can guess what they are for!

How do we control prosthetic hands?

Currently, the most advanced prosthetic hands are **myoelectric**: they work by recording the electrical impulses that travel from the brain to the muscles in the forearm, and map these impulses to simple movements like “open hand” or “close hand”.

By recording from a small number of locations on the forearm, we can control a small number of movements.

What if we could record from all the muscles in the forearm? What if we could record directly from a nerve?

AT THE EXHIBITION:

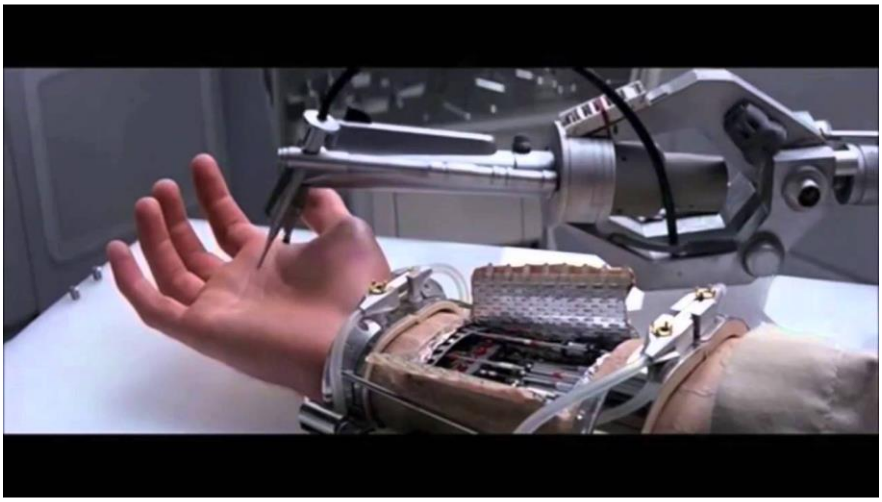
You will be able to see the electrical impulses produced by your own muscles as you move, and use them to control a robotic hand!

What about sensation?

Current myoelectric prosthetic hands do not provide any sensation to the user. When they touch an object, they do not give back any information about the texture of the object, temperature, pressure or pain.

Would you want a prosthetic hand that feels pain?

If you are familiar with **Star Wars**, you will have seen Luke Skywalker's prosthetic hand. In the film, how do they test that the prosthetic hand works correctly?
(Hint: which reflex protects us from painful stimuli?)



Proprioception: a sense we don't often think about

Prosthetic hands do not provide proprioception: this is the sense of knowing where our hands are in space, and how they are moving, without having to look at them. It is normally provided by sensors in the muscles and tendons, which are not there in a prosthetic hand.

How important is proprioception for the function of a prosthetic hand?

AT THE EXHIBITION:

Can you play the bongos? Play a quick game and explore the importance of both movement control and sensation in the function of prosthetic hands!

Modelling the musculoskeletal system

KS4 Curriculum links

Physics: The use of models
Forces and motion: acceleration caused by forces; Newton's First Law

Inverse and forward simulation

We have developed a mathematical model of the muscles and bones of the forearm and hand. This model includes information about where on the bones each muscle originates and inserts; estimates of the inertial properties of every segment (such as their mass); and estimates of the properties that determine the force each muscle produces (such as the muscle size and the stiffness of the tendon).

The model can simulate the function of the musculoskeletal system in two directions:

Forward: If we know how active each muscle is (by recording the electrical impulses), the model can calculate the resulting movement of the hand.

Inverse: If we know the movement of the hand (which we can record with various devices, such as the Leap Motion Controller you'll see at the exhibition), the model can calculate the activity of all the muscles required to produce this movement.

How can we use this model to control prosthetics?

If we record electrical impulses from forearm muscles, **forward** simulation of the model can tell us how the hand would have moved, if it was there. We can then make the prosthetic hand move in the same way.

Simulation of proprioception

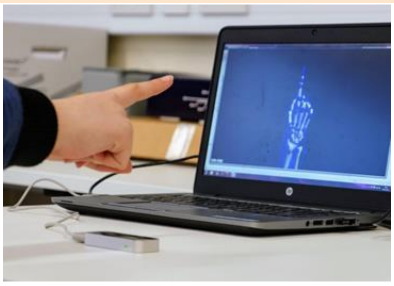
Our computer model includes mathematical descriptions of all the muscles, including their attachments to the bones of the hand.

This means that our model also includes descriptions of the sensors in the muscles and tendons that generate the sense of **proprioception**. So at the same time as controlling the prosthetic hand, the model can simulate the sense of proprioception.

How can this computer model help us make prosthetic hands **feel** more like real human hands?

AT THE EXHIBITION:

You will be able to interact with the model in the *inverse* direction, and see your hand muscles and bones in a virtual environment!



We will have a small device called Leap Motion Controller that measures your hand movements, and the model will estimate which muscles you are using to produce this movement.

Biomedical Engineering

Biomedical engineering is the application of engineering principles to medicine.

It is a very wide field that includes any technological advance that aims to improve human health, such as new materials, implants, prosthetics, drugs, imaging equipment, and computer software.

There are many different areas of biomedical engineering. Here are some examples:

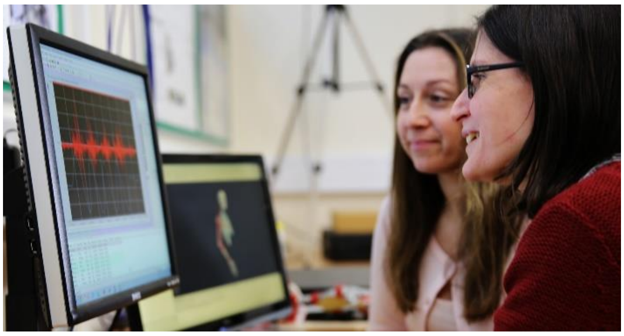
- Biomechanics including prosthetic devices and artificial organs
- Bioinstrumentation
- Biomaterials including tissue engineering & regenerative medicine
- Systems physiology and Physiological modelling
- Clinical engineering
- Rehabilitation engineering

You can find out more on the website of the Institute of Physics and Engineering in Medicine (ipem.ac.uk).

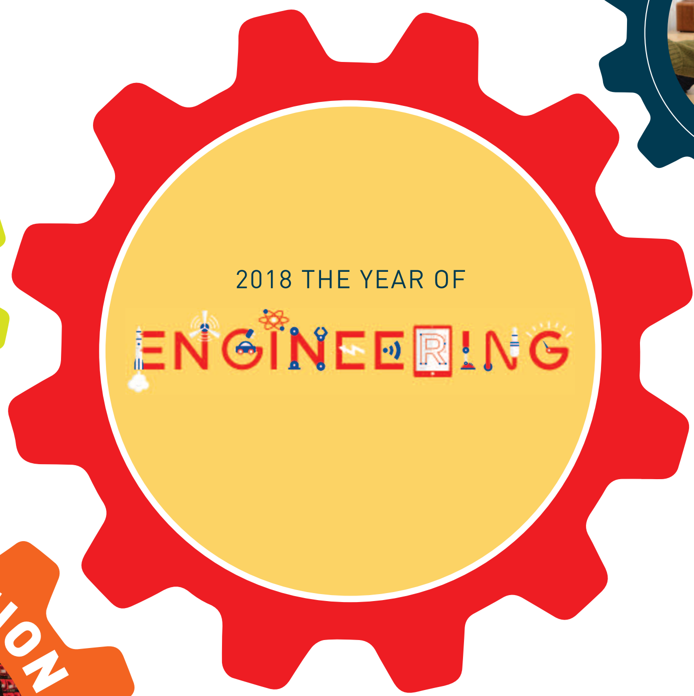
If you like solving problems and working in teams, and are interested in improving health, you too could be a biomedical engineer!

AT THE EXHIBITION:

Many of our volunteers at the stand are biomedical engineers. Make sure you talk to them about their day-to-day work!



Healthcare Engineering



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