**Presentation script**

**Slide 1:**

Hello, I’m Adam Metcalf. This is a quick presentation to discuss the progress of my PhD, titled ‘The development and Implementation of Low-Level Control Strategies for a robust and effective Low-cost rehabilitation robot for home use’. In this presentation I will justify the need for stroke rehabilitation robotics, discuss the current state of the field, talk about progress made so far and the plan for future work.

**Slide 2:**

It is statistically shown that the likelihood of having a Stroke increases with age. It has also been shown that the population of the UK is aging, with the Office for National Statistics projecting that 26.5% of the UK population will be aged 65 years or older by 2041. It is reasonable to extrapolate that there will be an increase in the numbers of Stroke patients with this greying of the population, resulting in an increase in demand for rehabilitation services.

It is understood that rehabilitation is most effective when applied intensively and early after Stroke, which places great strain on the NHS. This is essentially a problem of supply and demand, where the availability for rehabilitation is struggling to be met now, let alone in the years to come. It should be noted that the neurofunctional mechanisms for recovery are not well understood

**Slide 3:**

The effects of stroke depend on the region of the brain which is affected. Here are of the common motor control effects. Damage to motor control of limbs is common, with a study by Sommerfield et al in 2004 showing that up to 80% of stroke patients suffering from some form of motor control deficit.

**Slide 4:**

The increasing lack of sufficient access to rehabilitation after Stroke has led to a rise in the use of robotics for post-Stroke rehabilitation. Rehabilitation Robotic devices for Stroke Rehabilitation are classified in a 3 different ways: Targeted limb, mechanical structure and use class.

* For targeted limb: Upper limb devices are designed for the rehabilitation of shoulder, elbow, hands, grip etc. Lower Limb devices are designed for gait training, ankle rehabilitation etc.
* For mechanical structure: Devices are exoskeleton, where the limb is supported by a structure which mimics the skeleton, or end effector based, which contact the patient only at the distal part of the limb (the hand in the case of upper limb devices).
* For use class: Class 1 devices are expensive and are intended for supervised lab or clinic-based use. Class 2 devices are less expensive and are designed for unsupervised use in the home environment.

**Slide 5:**

There were some clear outcomes from the literature review, including some very recent findings of the RATULS study in Newcastle (Robot Assisted Training for the Upper Limb after Stroke). One of the main outcomes of the RATULS study is that the use of rehabilitation robotic devices (specifically the InMOTION arm, or MIT-MANUS) is that robotic solutions did not improve patient outcomes greater than usual care and were not cost effective.

Johnson et al (2007) identified a need to develop low cost rehabilitation robotic solutions, and that home use robots with low clinical supervision would be beneficial.

Marchal-Cresco and Reinkensmeyer (2009) identified a need to compare low-level control schemes with traditional therapy.

**Slide 6:**

An overview of the MyPAM system.

**Slide 7:**

The MyPAM currently has a highly coupled systems architecture, which is mainly due to the age of the project and the number of people that have worked on it. A highly coupled architecture is undesirable because it means that future changes are hard to implement, for example it is not possible to move some of the DAQ away from the FPGA and onto separate chips without a significant amount of reprogramming. Further to this, any errors such as TCP communication faults tend to propagate throughout the code and cause a crash of the entire system.

Trajectory generation is interpolated point along a linear path, where intermediate targets are generated in the game. This has disadvantages also. A smooth trajectory is not generated, and also there are times where no intermediate points are generated between the start and end positions, leading to large accelerations which are uncomfortable and potentially dangerous for the user.

**Slide 8:**

Admittance control is based on a position inner control loop. The interaction force is used to modulate the desired position by a virtual mass/spring/damper arrangement.

Devices using Admittance control can become unstable in stiff environments, and it could be argued that admittance control is most suited compliant environments (ie patients with a high level of limb weakness, low level of spacitcity).

**Slide 9:**

Impedance control is based on a force inner control loop. The position of the robot is used to modulate the desired force by a virtual mass/spring/damper arrangement.

In general, devices using impedance control are stable in stiff environments, and it could be argued that impedance control is the most suitable scheme for patients with a high level of spasticity.

**Slide 10:**

I will now discuss the current progress made to date. This includes the justification and generation of a smooth trajectory, and integration into the current architecture. The creation of an integrated end effector/force sensor and the creation of an Admittance control scheme.

**Slide 11:**

The trajectory generation responsibility was removed from the game and implemented into the low-level controller for point-to-point game types. This has a number of benefits:

1. A smooth trajectory can be generated, and the safety of the user can be monitored at source.
2. There is an allowance for the integration of attractors and deflectors in future games.

The minimum jerk trajectory was selected as the trajectory of choice. Easily implemented, widely used and closely resembles the trajectory of a healthy reaching movement.

**Slide 12:**

A necessary component for the advanced low-level control schemes is the ability to measure the interaction force at the end-effector. Industrial force sensors are costly – does not meet the specifications of a low-cost device. There are a few low-cost solutions available, but there are downsides.

Strain-based force sensing is noisy and requires a lot of signal conditioning.

Piezoelectric force sensors are subject to drift when held at a holding force.

**Slide 13:**

A vital part of the integrated end-effector/force sensor is the transformation from the 4 raw voltage readings to forces resolved into the x and y directions. This presents mathematic difficulties which, whilst probably not insurmountable, create significant problems. These difficulties boil down to essentially 2 main problems:

1: The hyperplastic silicon material does not deform linearly ( k does not equal f time x).

2: The magnetic field interactions of the 4 magnets in a complex 3D arrangement are difficult to establish and model.

Much modelling was attempted to create a function which could transform the raw voltage readings into Fx and Fy, but the assumptions made were unreasonable and the model was highly inaccurate.

For this reason, and Neural Network was built and trained to classify the system, allowing the forces to be derived from the inputs.

**Slide 14:**

Talk through block diagram.

**Slide 15:**

Placeholder.

**Slide 16:**

**Rearchitecture:**

MyPAM is an established project which has been worked on by many people over many iterations. The embedded code on the myRIO has been worked on by at least 8 people previously.