3D Stroke Rehabilitation using Electrical Stimulation and Robotics

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SAIL 3D Stroke Rehabilitation

Introduction

Scale and cost of stroke

There are over 150,000 new stroke cases every year costing the NHS more than £3 billion annually. Stroke is the foremost cause of adult disability in the UK.

Reaching

A third of the surviving patients suffer from some degree of motor disability and only 5% of severely impaired patients regain full upper limb function. Many stroke patients have difficulties with arm extension due to over-active biceps.

Rehabilitation technologies

More effective technologies are needed to aid recovery of motor function. New technologies should also aim to bring rehabilitation closer to the patients' homes and bring about wider economic benefits through patients being less dependent on carers and statutory services.

How it helps?

Past studies have shown that recovery of the patients can be aided by: intensive treatment, repetitive functional tasks and maximal voluntary actions combined with electrical stimulation.

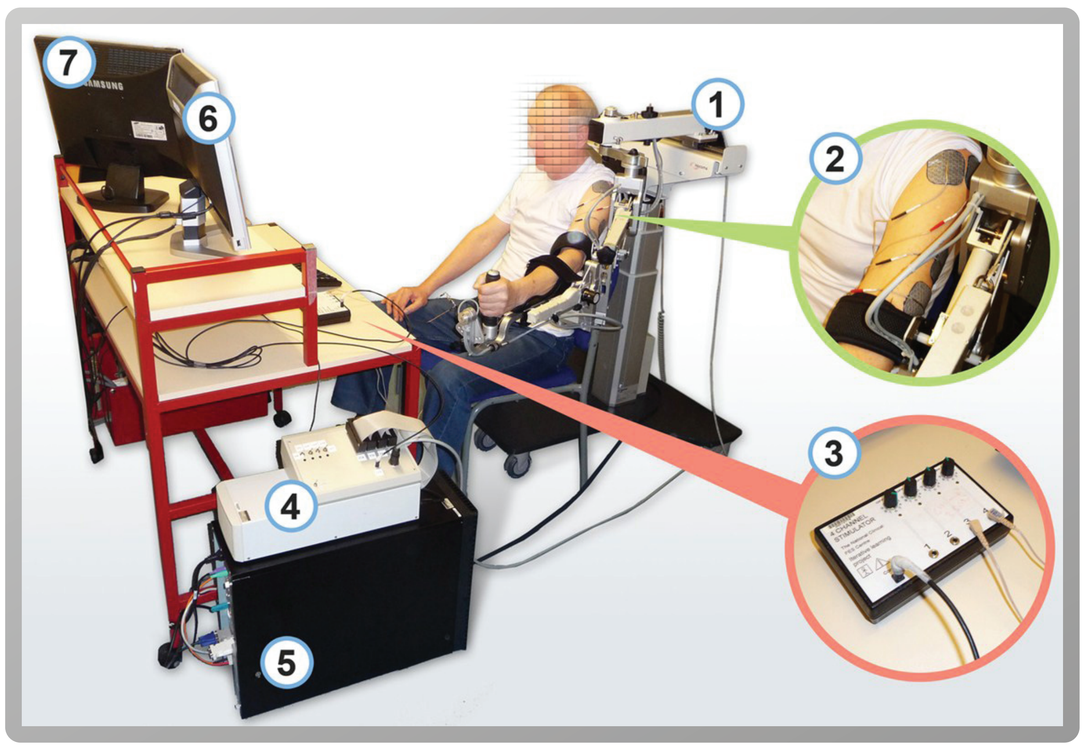
Stimulation Assistance through Iterative Learning (SAIL) System

Chosen technology

The SAIL system has been developed at the University of Southampton and uses functional electrical stimulation (FES), an upper limb robotic support, and iterative learning control (ILC) to precisely mediate the assistance given to patients to complete tracking tasks. ILC is an advanced technique typically used in industrial robotics.

System structure

1) ArmeoSpring®, 2) surface electrodes on triceps and anterior deltoid, 3) FES stimulator, 4) realtime processor and interface module, 5) PC, 6) monitor displaying task, and 7) operator monitor.



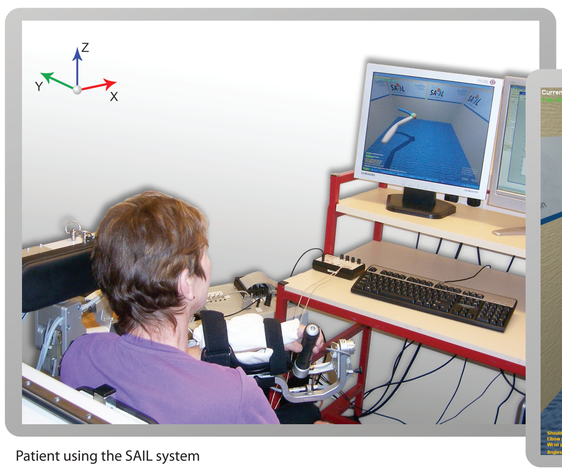
What happens during a session?

1. Patients have gel pads applied over their triceps and anterior deltoid for FES and are positioned into the ArmeoSpring®.
2. A reachable area is set, this defines the tracking trajectories.
3. A fixed set of trajectories are used to assess unassisted performances of patients before (and after) the session.
4. A series of reaching tasks involving trajectories determined by varying elbow and shoulder angles are completed. Each task consists of the same movement being repeated six times, with controlled-FES assistance.

The ILC controller gathers information during each trial aiming to improve the tracking performance by tuning the stimulation signal.

System software

One monitor displays a graphical user interface which allows the physiotherapist to customise the parameters which define the task and controllers. Another runs a 3D virtual reality environment which displays a graphic of their arm in real-time, together with the trajectory tracking task. The aim of the tracking task is for the patient to track a sphere which travels along the trajectory at various speeds. The colour of the patient's hand changes with respect to tracking precision. Visual feedback of performance is also given by an error percentage score displayed after each set of trials.



Patient using the SAIL system

3D virtual reality environment

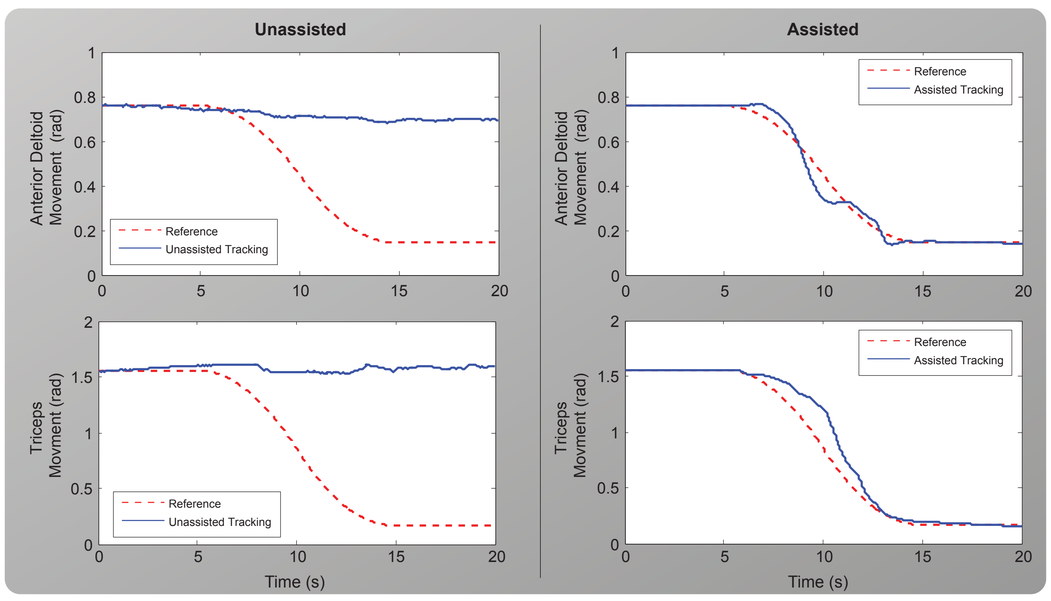
Clinical Trial

Test on unimpaired participants

11 unimpaired participants took part in the pilot study to ensure that the system provides smooth and comfortable assistance to the arm. During each test session, the participant does not apply any voluntary effort and FES alone drives the task. The trial-to-trial improvements are significant with up to 30% of the participants achieving almost perfect tracking performance.

Clinical trial with stroke patients

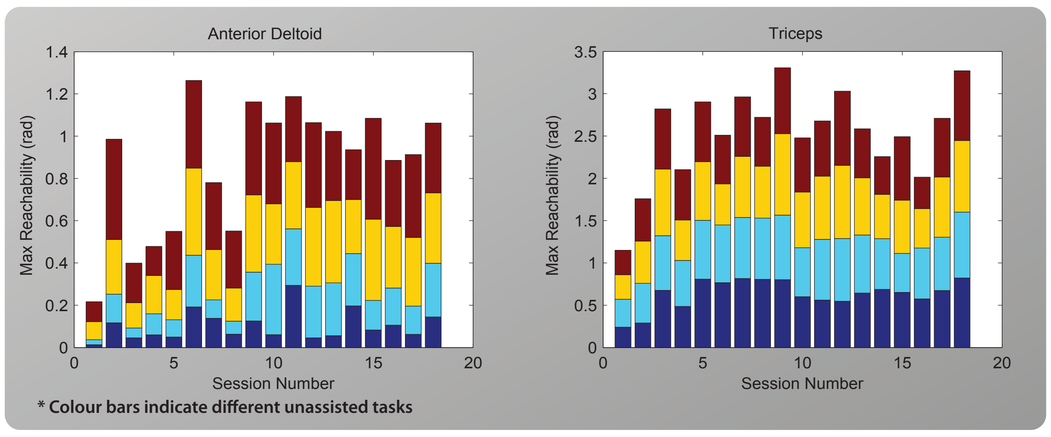
5 stroke patients have recently completed clinical trials involving 18 treatment sessions and the performance of their assisted and unassisted tracking has been recorded throughout. The figure below shows that FES very effectively moves the arm to track the trajectory.



Comparison of unassisted and assisted performance on anterior deltoid and triceps

Clinical results

After 18 treatment sessions, the performance and reachability of the stroke patients significantly increased in most of the cases. Statistical analysis is now being performed. The figure below shows an increase in arm function over the course of the clinical trial.



Growth in the reachable range of anterior deltoid and triceps over the 18 sessions

Conclusion

A platform for stroke rehabilitation has been developed and constructed, comprising of a 3D rehabilitation mechanical support and FES system to achieve precise control of human arm movement. The technology is designed to help stroke patients train their upper limb muscles during reaching tasks using electrical stimulation to augment their remaining movement. Clinical trial results confirmed that accurate tracking can be achieved with FES assistance and that the treatment improves unassisted performance. Future research will aim to bring the system into patients' homes.

This work is supported by EPSRC grants EP/I01909X/1 and EP/G014078/1

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