Robots for rehabilitation

The University of Hertfordshire hosted a KT-EQUAL workshop in November 2009 on the subject of robots for rehabilitation. The overall message from the workshop was robots have significant potential for healthcare delivery, with technology able to enhance the face-to-face delivery of specific rehabilitative interventions.

However, there are significant research challenges in developing and testing rehabilitation robots so that they meet the requirements of end users. The technology must be capable of improving a person's impaired or allayed function. To do this, robots have to be able to recognise and respond to the complexity of individual human physiology and behaviour so they can mirror established rehabilitative interventions. In other words, robots have to understand how humans work.

There are also significant social implications for the increased use of robots in society. A range of different research disciplines have to work with industry, and involve both clinical staff and end users, if the research is to be successful in moving to the mainstream.

Through the EQUAL programme, among others, the Engineering and Physical Sciences Research Council has supported a number of research projects in the UK which are concerned with developing and testing robots for rehabilitation. By showcasing significant research in this workshop, we sought to dispel some of the unhelpful views of robots which are common within our society, and to stimulate debate regarding how robots might enhance the delivery of rehabilitation to people of all ages.

Programme

Why focus on rehabilitation?

The first speaker of the day and organiser of the event, Farshid Amirabdollahian, confirmed that there is a general enhanced interest in robotic applications. This is due to a combination of demographic trends resulting in an ageing population, and a burgeoning interest in technology for fitness and potentially for rehabilitation being promoted through gaming devices such as the Nintendo Wii.

Rehabilitation is an important aspect of health and social care delivery, for which the potential of technology is yet to be fully exploited. Traditional forms of rehabilitation are costly; for example, a high proportion of the costs of stroke aftercare can be attributed to rehabilitation. Moreover, many people do not receive the rehabilitation they require, with demand generally outstripping supply. Existing methods of delivering rehabilitation are time-intensive (and therefore cost-intensive), with interventions usually provided through face-to-face contact with a therapist.

However, some interventions depend for their success on repetitive functional movements (which do not necessarily need a qualified therapist to attend), or on continued practice in which the user has to be motivated enough to continue independently. So there are many potential uses for technology, and a number of significant UK and international research groups are involved in cutting-edge research to create and test robotic applications for rehabilitation.

What are robots?

Farshid Amirabdollahian and William Harwin provided an overview of the 'state of the art' from different but overlapping perspectives. Farshid concentrated on robots as healthcare applications, and William then described the different functions that robots can fulfill, thus illustrating the range and depth of possibilities.

Healthcare applications described by Farshid included:

- **assistive robots** which help the user to perform a function that they would otherwise be unable to perform by assisting or retarding movement (for example, robotic exoskeletons)
- **intelligent prosthetic limbs** which interface with the muscles and nerves of the user

- **robots for physical rehabilitation** which encourage the user to undertake prescribed repetitive movements (for example, the Gentle/S robot for stroke rehabilitation, and MIT-Manus, which is currently being subjected to a large clinical trial)

- **social mediators and companions** which respond to sense of touch and sounds (for example, Kaspar, Paro seal)

- **robots for surgery** (for example, Davinci, cyber knife, activating laparoscopic machines)

- **robots to facilitate physiological intervention** (for example, microbots and nanobots, which manipulate blood clots within muscles)

William Harwin provided illustrations of different robotic applications, including robots in manufacturing, the Google search engine as a form of robot, robots as mechanical servants in the home, robots as tools for interactions, robots to extend physiological proprioception, and robots for stroke and spine injury rehabilitation. He also raised the possibilities of use of using computers in education settings for people with motor disabilities, and the use of 'cobots' to assist residents in care homes. A walking frame that increases ability to be able to navigate is one example of an adapted cobot.

The presentation highlighted some of the challenges that exist even with technologies that have been in development for some considerable time. For example, the Manus robot, an early prototype which is designed to be attached to a wheelchair, requires that the user has good visual acuity. Robots have to take into account human mechanical and neural systems and provide interventions in response to predetermined requirements.

Engaging users in robot development

Rui Louerio identified a number of important principles that must be taken into account when engaging end users in the development and testing of robots, using the on-going work on the Gentle/G robot as illustration. User engagement must make sure that researchers take into account the full range of users' needs. Also, the resulting device must be customisable so the robot's behaviour can be adapted to suit each individual user.

As well as clinical utility, to be successful a device will incorporate practical and social acceptability. The appearance of healthcare robots was used to illustrate this important point. For example, should the robot be human-like? If so, what gender should they be, and what personality and facial expression should be incorporated into the robot? What size is optimal for use in different settings? An overriding principle is that the resulting design should focus on simplicity, as complexity excludes users.

One significant and ongoing challenge is how to enhance users' motivation to engage with any form of rehabilitation, particularly that which involves repetitive movement. It has been demonstrated that rehabilitation involving playing a game over the internet can encourage equally good quality of movement while also being more motivating than traditional exercises. This raises questions about use of the Nintendo Wii in clinical contexts, where the system can be customised to meet the needs of the individual user.

Making sure that devices meet health and social care requirements

Bipin Bakta provided an overview of the clinical issues relevant to device development. Robust clinical testing is needed if this type of technology is to be adopted by the NHS.

Rehabilitation robots are complex interventions – taking into account not only the device itself, but also the interactions of clinical staff, patients and the environment. If such devices are to be used within the NHS, established systems for evaluation should be used. The Medical Research Council's framework for evaluating complex interventions (MRC, 2008) provides a widely-used health intervention structure.

For instance, stroke results in a broad range of impairments (including spasticity, weakness, loss of coordination, shoulder pain and perceptual problems) which can all limit functionally useful limb movement. These complex impairments need to be considered as targets of intervention during device development. The interventions envisaged for the device should be part of the patient pathway.

Central to the development of rehabilitation device is end-user engagement. This should allow people to participate with varying levels of disability, including those with communication and other cognitive impairments. It should also involve expert clinical staff to ensure that the device has clinical utility.

The experiences of Bipin Bhakta also mirrored those of Rui Louerio in that development has to consider appropriateness within a hospital department, including set-up time, capital and maintenance costs. The device also has to be readily understood by users and therapists, and provide comprehensible feedback. For adoption by the NHS, appropriate study designs must be used, and economic considerations are particularly important if the device is to have a realistic chance of being incorporated into routine clinical practice.

Perspectives of the rehabilitation practitioner

A presentation by Karen Baker and Diane Playford summarised the issues from a physiotherapy perspective, using stroke as an example. Many of the points raised by Bipin Bakta were reiterated.

Karen emphasised the complexity of the healthcare delivery setting, which may include the homes of individual users. She also repeated that stroke is a very complex condition with many resulting disabilities, and therefore that the numbers of people that might benefit from some devices is comparatively small. Devices need to be both effective and cost-effective, engaging, easy to use and maintain, and with a small footprint. Users need to be properly trained in use of the technology, and untrained carers also need to be able to use it. The Medical Research Council's framework for complex interventions was raised again as being important for evaluating technology to be used within health service settings, but this was also tempered with the need to integrate a range of evaluation strategies.

The interface with neuroscience

The complexity of mirroring even the most simple human movement was described by Alan Wing.

Neuroscience can involve experiments on healthy subjects to obtain a detailed understanding of normal processes. Alan described a series of three related projects concerned with different levels of resistance, namely acceleration, velocity and position. The results are important for the functional design of robots.

Conversely, using robots in this form of investigation can also assist our understanding of complex models of human motor control. To grip objects we have to coordinate, predict and decide how tightly the object has to be held. Grip has to change when the weight of the object changes and so we have to predict how tightly it needs to be held. Prediction changes to control the movement before it is completed. Using both hands involves grip force, load forces and correlation between the two hands. If the weight changes, a strong correlation is required between both hands. To examine changes in prediction and reflexes, Alan used a single case study of a person with had severe left impairment and spatial attentional problems following a stroke.

Etienne Burdett developed this theme further by describing a number of projects in which he is involved. He stated that neuromotor learning can inform neurorehabilitation, but not fully explain it. He reiterated Alan's point that the brain is constantly learning and adapting to compensate for interactions and instability during motor learning. The brain tries to minimise error and to use energy efficiently, but damage can impede this process.

Human motor learning with healthy subjects can be used to explore device potential. These principles are being used by the MIT-Manus group. The MIT-Manus robot is a simple training device with a restraint and provision of feedback. The model is coded in the muscle rather than the joint coordinates, and it is able to provide feedback on both force and length.

Robotics and autism

The final presentation of the day, by Kerstin Dautenhahn, was concerned with robots for children with autism who cannot play. The literature demonstrates that children with autism like interacting with computers in preference to people. In this instance, the robot is able to act as a social mediator between the child, the robot and another person to encourage collaborative play.

Kaspar is one example of a robot that can be remotely controlled by the carer. A second example is the Aibo robot, which has been subjected to a 10 week long-term study inspired by non-directed play therapy as part of the Aurora project. Detailed play grids to code and analyse behaviour were used with promising results. A further proof-of-concept study has validated the extent to which the robot is adaptive and can reward for appropriate social behaviour.

Researchers in a completed EU study, IROMEC, designed, built and tested a new robotic toy which can be tailored to user needs. One key step was the development of scenarios involving teachers, parents and therapists. Kerstin emphasised the need for an interdisciplinary approach to research in robot assisted play.

What the event demonstrated

Questions and discussion points raised the following issues:

- If socially-inclusive rehabilitation robots are to be developed, users have to be involved, with users including therapists as well as end users of services. Work needs to be undertaken to identify the mechanisms by which robot development leads to technology that is user-friendly and fit for purpose. Good simple design must be promoted.

- The social implications of robots can extend beyond the functional outcomes. This aspect needs further research, as does the capacity that robots have to create behavioural change.

- Training needs of health and social care professionals have to be addressed. Health and social care services have to be redesigned to incorporate the use of robots. Significant investment is necessary to create the necessary changes.

- Robots are devices which will age and wear out, and they need power to operate. So the maintenance costs of equipment may outweigh its capital costs. It is important that systems are reliable and safe. Standards for safety may become an EU requirement (and controls are already in place for surgical robots). New ways of powering robots, such as solar power, need to be investigated.

- Robust clinical evaluation of robotic devices is required to provide evidence of clinical effectiveness and to provide the necessary clinical confidence for embedding into statutory service provision. Technologists will have to become familiar with health services research methodologies. There is significant need for interdisciplinary collaborations and knowledge transfer.

- The personalisation agenda in health and social care will provide additional channels for robotic applications and ubiquitous computing in the home. Wearable devices will provide further possibilities. The Nintendo Wii has already raised possibilities and expectations. The demand is out there, but good marketing of devices is required. This will require us to learn from others; for example, Japan has a SMART centre within the community.

Relevant web resources and references

Nintendo Wii http://www.wiihabilitation.co.uk/home.shtml

Robotic exoskeleton
http://www.bw.ctw.utwente.nl/research/projects/lopes.doc/index.html

Gentle/s robot http://www.gentle.reading.ac.uk/

Kaspar http://kaspar.feis.herts.ac.uk

Paro seal http://paro.jp/english/index.html

Davinci http://www.intuitivesurgical.com/index.aspx)

Cyberknife http://www.cyberknife.com/CyberknifeTreat.aspx

Microbots http://robots.mit.edu/projects/microbots/index.html

Nanobots http://www.nanobot.info/

Cobots http://www.mech.northwestern.edu/peshkin/cobot/

Gentle/G http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05209509

Richard Lilford' work http://www.hddt.bham.ac.uk/lilford.htm

MIT-Manus http://meche.mit.edu/

Aibo robot http://support.sony-europe.com/aibo/

IROMEC http://www.iromec.org/

AuRoRA http://www.aurora-project.com/

Medical Research Council (2008) A framework for development and evaluation of RCTs for complex interventions to improve health.
www.mrc.ac.uk/Fundingopportunities/Highlightnotices/.../index.htm