Institution: University of Portsmouth

Unit of Assessment: 11 Computer Science and Informatics

Title of case study: Improved mobility and quality of life for children with disabilities

1. Summary of the impact

Research at the University of Portsmouth (UoP) has created new user-friendly control, navigation and communication systems for powered-wheelchairs that have made a significant and positive impact on the lives of users. These have given many disabled children and adults an opportunity for independent mobility, some for the first time.

The systems have been used in six special schools and institutions (*including RNIB and NHS*) and many private homes. Economic impact in reducing the need for carers alone has been estimated at more than £250,000 p.a and the devices have also changed some professional services.

2. Underpinning research

Before 1995, powered-wheelchairs were mainly provided to people with sufficient dexterity to control a joystick. Research at the UoP has resulted in new features for powered wheelchairs that included: effort-reduction, predictive and interactive Artificial Intelligence, so that children could drive for longer and in some cases for the first time. Research was based on many years of work by the Systems Engineering Research Group at the UoP into climbing and walking robots and automated guided vehicles. The work was led by the UoP in collaboration with Chailey Heritage School (CH) and Sussex Community NHS Trust.

The original track systems to guide wheelchairs were created by Langner and Sanders and prototype systems to follow a path parallel to a wall and collision avoidance systems were developed by Sanders, Stott and Goodwin 97-01 [Key-Ref 1]. Sensors were created to safely detect the environment and allow off-track driving. Mechanical bumpers were also introduced although later research suggested that occasional minor "crashes" could improve learning. Various input devices were created for children with different disabilities, and new object-proximity-sensing systems provided collision avoidance. Further research introduced veer-correction that reduced tiredness and wall and doorway collisions [Extra-Ref 1]. New switches led to improved mobility and manoeuvring and new input devices were created that were easier for children to use [Key-Ref 2]. Further development was made to include Artificial Iintelligence to tolerate involuntary movements and provide proportional-response controls (09-13) [Key-Ref 3 and Extra-Ref 2]. Original prototype systems were featured in the ITV program "Good for You" and they and the latest systems can be seen at https://www.facebook.com/PortsmouthUniversityMobility.

A recent development was the creation of a Scanning Collision Avoidance Device (SCAD), which made innovative use of cheap rotating ultra-sonic devices that transmit pulses during stepped periods of rotation. Early systems gave audible warnings of collision (*for example, for blind children*). New systems were created to increase the sampling rate, which allowed SCAD to assist with steering without any need for helpers. These systems are being connected to expert systems for interpreting hand movements and tremors [Key-Ref 3] and AI systems for improved control [Extra-Ref 3].

Further investigation into communications systems led to a new system that allowed a user to change the function of their input device between wheelchair control and remote device control, and new infra-red optical detectors with background suppression were included for drivers lacking spatial awareness [Sanders / Langner 10-12]. All these new features have been used in several schools and institutions, allowing many children to have access to powered-wheelchairs for the first time.

The Portsmouth team was led by Dr David Sanders (1989-2013 now a Reader), with: Dr Ian Stott (Lecturer 1995-2002 & 2010-2013), Dr Giles Tewkesbury (1995-2013 now Principal Lecturer), Dr Alexander Gegov (2000-2013 now a Reader) and Dr Mike Goodwin (Fellow 1995-2002); whilst work at CH was led by Dr Martin Langner (1992-2013 now Senior Engineer).

3. References to the research:

Three key references are:

Key-Ref 1. Sanders DA and Stott IJ (1999). A new prototype intelligent mobility system to assist powered wheelchair users. Industrial Robot: An International Journal, Vol 26, Issue: 6, pp 466-475. DOI: 10.1108/01439919910296746

Key-Ref 2. Sanders D, Langner M, Tewkesbury GE, (2010). Improving wheelchair-driving using a sensor system to control wheelchair-veer and variable-switches as an alternative to digital-switches or joysticks, Industrial Robot: An International Journal, Vol. 37 Issue: 2, pp.157 – 167. DOI: 10.1108/01439911011018939

Key-Ref 3. Sanders D, Stott I; Graham-Jones J et al, (2011). Expert system to interpret hand tremor and provide joystick position signals for powered wheelchairs with ultrasonic sensor systems, Industrial Robot: An International Journal, Vol. 38 Issue: 6, pp.585 – 598. DOI: 10.1108/01439911111179101

Three other references are:

Extra-Ref 1. Stott IJ and Sanders DA, (2000). New powered wheelchair systems for the rehabilitation of some severely disabled users. Int J Rehabil Res, Volume 23(3), pp.149-153. http://www.ncbi.nlm.nih.gov/pubmed/11131614

Extra-Ref 2. Langner M & Sanders D, (2008). Controlling wheelchair direction on slopes, Journal of Assistive Technologies, Vol. 2 Issue: 2, pp.32-41. DOI: 10.1108/17549450200800016

Extra-Ref 3. Sanders D, Tewkesbury G, Stott I et al, (2011). Simple expert systems to improve an ultrasonic sensor-system for a tele-operated mobile-robot, Sensor Review, Vol. 31 Issue: 3, pp.246-260. DOI: 10.1108/02602281111140029

The basis for the powered wheelchair research came from grants with Nuclear Electric and PortTech Ltd that led to a European grant from 96 to 98 [“Walking Intelligent Robots etc” £694,700 (Collie (Professor to 99) and Sanders]. Two further grants took that research into a new direction of powered mobility for people with disabilities: an Action Research Charity Research Grant for £30K (Sanders) from 95 to 98 and an EPSRC grant for £200K from 96-98 [“Design & manufacture for rehabilitation & mobility” (Sanders)]. That early work led to various projects and grants with QED Ltd, CH and the NHS and the nearly two decades of collaboration described in this case study.

4. Details of the impact

Our research led to the creation of new user-friendly control, navigation and communication systems for powered-wheelchairs that have made a significant and positive impact on the lives of disabled individuals [Sources 1-6]. New technologies and processes have been adopted and approximately 1500 people benefited from using the new systems between 08 and 13 (*mainly children and young people with complex physical disabilities and health needs*) [Sources 7,8]. The new systems have been used in schools (e.g: RNIB Sunshine House, Grove Park, Chailey Heritage, Victoria Specialist College), homes (e.g: RNIB Children's Home and Finches residential home) and many private dwellings; allowing many children to use powered-wheelchairs for the first time. Prototype original systems were featured in the ITV program “Good for You” and they and the latest systems can be seen at: https://www.facebook.com/PortsmouthUniversityMobility.
The initial work with the Action Research Charity and a wheelchair manufacturer (QED) resulted in a new wheelchair design and improved joystick, which won the Gold Award in the special needs category for innovation at the Education Technology Awards (*presented by David Blunkett*) [Source 7]. More recently in 2011, Langner received a prestigious award for the research from Well Child, a national children's charity [Source 2].
Following a series of symposia run by Sanders and attended by staff from the NHS and CH [Source 7], subsequent meetings and conversations led to NHS and CH supporting the research

by conducting testing and clinical trials, whilst CH and a spinoff company (*Langner Associates*) built the new devices. Other industrial partners, including QED and a software company (Key Industrial Software Solutions - KISS), took part in KTPs, secondments and fellowships to support creating the sensor systems and developing the AI systems [Source 4].
Major impact may be divided into three categories: (a) Health Impact - Improved quality of life; (b) Economic impact; and (c) Impact on professional services.

(a). **Health Impact** - **Improved quality of life**
Users' quality of life has been significantly enhanced. In particular, obstacle detection and veer-correction systems have allowed children with limited dexterity to use powered-wheelchairs for the first time [Source 1]. The research has also enabled users to drive for longer with greater protection so that they can manoeuvre in new environments, such as driving on pavements and incorporating more activities into their lives. It has made a significant positive difference to these people's lives, giving disabled individuals more confidence, independence and freedom [Source 1-6]. The systems have been used in schools and institutions as well as in private homes.
(b). **Economic impact**
The research has led to significantly reduced healthcare costs. For example, reducing the need for carers alone has been estimated at more than £250,000 p.a. [Sources 7, 8]. Further, costs of the systems have also been significantly reduced due to new designs and use of cheaper alternatives. For example, SCAD has been reduced from about £3,150 per unit in 2008 to about £2,350 in 2013.
(c). **Impact on professional services**
The research has also prompted changes in professional service practices in that powered-wheelchairs are now always considered as an option [Sources 8-9]. The new systems have been applied in schools, NHS, various disabled community groups, in private homes and for individuals. New technical standards and clinical protocols have been introduced [Sources 5,7-9]. Professional guidelines and training have been informed by the research and health outcomes have improved because of the availability of the new systems and the new ways that people are trained on them. Changes have also been made to patient care practices [Sources 5,8,9].

Research at UoP has also created fly-by-wire systems for wheelchairs, which is being used by children there. Working in partnership, the team has identified ways of measuring and improving user competence, leading to new methodologies currently being used by NHS therapists to teach users how to drive. Research also supported analysis of driver behaviour at CH before, during and after collisions. Further investigations into assisted steering and the effects of system and helper intervention led to the development of algorithms which allowed users to crash safely on occasion so that they could learn corrective behaviours. That technology is being used now but is also being constantly improved; for example, reduction of scanning times has led to new, faster and responsive processes that are replacing some of the older systems in schools and institutions, hence further improving the lives of the users. [Sources 7,8].

5. Sources to corroborate the impact.

A selection of sources is provided, including statements, articles and video footage:

1. **Statement - Parent of child using the system**: The parent was told by the NHS that his child could never use a powered wheelchair. Despite that, because of the new systems his child is now using a chair. He confirmed that the systems are improving the ability of his child to control his wheelchair and his quality of life has improved.
2. **Statement - Head of Chailey Heritage School**. A charitable special school for young people with complex physical disabilities that is using the new systems. He confirms that the pioneering technology was created in collaboration with the University and that the University provided relevant knowledge and skills and access to the latest technology and facilities. The new systems have made a real difference to the lives of many children and young people. Approximately 1500 children have had access to the systems. Langner received a prestigious award from Well Being.

3. **Statement - Head of Futures at Chailey Heritage** is responsible for transition provision for young adults with profound disabilities and high healthcare needs. He confirmed that all the systems and devices are in use and accomplished clinicians are using the new products.
4. **Statement - General Manager at Key Industrial Software Systems Ltd**; confirmed collaboration with industrial partners, special schools and NHS and that they have seen outstanding results being achieved with the AI systems. The children began using the simple early systems and have now moved on to the more intelligent systems as they have grown older.
5. **Statement - Principal Medical Engineer, Bath Institute of Medical Engineering / Royal United Hospital**, states that research findings are having an impact on health professionals in the conduct of their work, and that the quality of professional services for children using powered-wheelchairs has improved. New procedures have been introduced and children are benefiting. Research has changed the way that staff allocate equipment and assess children. For the first time, wheelchair systems are considered a viable option for a wider range of children.
6. **Video footage -** https://www.facebook.com/PortsmouthUniversityMobility
7. **Article**. The work has featured in several newspapers and industry publications but this is the longest non-academic article. It describes the start of the research (*as clinical trials were beginning*) and why children needed the systems. It confirms that between about 1500 to 2000 people have used the systems. Technical standards and clinical protocols have been introduced and new policy has been implemented. Patient health outcomes have improved and quality of life enhanced and costs of healthcare have reduced. It describes the sensor fusion research by UoP being incorporated into new algorithms that led to the introduction of contact-less proximity sensing. That created a new approach to manoeuvring around complex environments (*using ultrasonics and optics with variable range settings*).
Fox NJ (2012). "Getting around using tracks and intelligent wheelchairs". Intelligent Mobility, pp 277 - 283. ISSN 1472-7633.
8. **Review paper** that places the work in context with other work in the area and describes media coverage (*BBC, European Business News (euronews), ITV*) and why children needed the systems. It features a parent explaining that need and another explaining the difference it has made. Between 1500 and 2500 children and young people are estimated to have had access to the systems in the UK. Prototypes of the new devices are shown and it describes how the exploration of background suppression and light reflection improved the systems, whilst the ability to anticipate corners and obstructions led to new collision avoidance techniques and revisions in controller strategies. The work has improved independent mobility for people with severe motor disabilities and given children the opportunity to transport themselves. Professional guidelines and training have been informed by the research, and professional service practices have also changed. The new systems have been applied across a wide range of user-groups and new technical standards and clinical protocols have been introduced. The systems have been used in more than six schools and institutions as well as in private homes. Practices have been influenced, health outcomes have improved and changes have been made to patient care practices.
Rogers IA (2012). "A review of powered assistive mobility systems". Journal of Computing in Systems and Engineering, pp 237-264. ISSN 1472-9083.
9. **Statement - Professor of Rehab at Surrey University** / **Deputy Director, Institute of Orthopaedics at Royal National Orthopaedic Hospital.** Confirmed that quality and efficiency of professional services improved because of the research and professional bodies have used research results to define best practice. Practitioners and professionals are using the systems and research findings in their work. Quality and efficiency of professional services has improved and professional bodies have used the research to define best practice. Performance of medical care at Chailey has improved and new, updated and enhanced technical standards and protocols have been introduced. Spin-out businesses have been created and new technologies and processes have been adopted. Clinicians have drawn on the research and some new policy has been implemented. Delivery of services has changed to incorporate the new devices. The policy debate has been stimulated and informed and patient health outcomes have improved. Decisions by health services and regulatory authorities have been informed and the research is influencing changes to professional standards, guidelines, practices and training. Powered wheelchair systems are now always considered as an option.