Intelligent powered wheelchairs

Session Proposal

The session at the conference will explore the use of artificial intelligence to share control of a powered-wheelchair between a wheelchair user and intelligent sensor systems.

The team will present the most recent findings from the projects in a series of six papers within a session at the conference. These papers will provide updates to describe progress and research since the sessions presented in 2020:

- IEEE 10th International Conference on Intelligent Systems. Papers available in IEEE Xplore and at: https://sites.google.com/port.ac.uk/workshop1-ieee-2020/home
- IEEE sponsored SAI Conference on Intelligent Systems. Published by Springer and at: https://sites.google.com/port.ac.uk/workshop2-intellisys2020/home

This project is investigating the novel use of Shared Control, Sensors and Artificial Intelligence to create systems that will significantly and positively impact on the lives of powered-wheelchair users. People are able to drive for longer and in some cases for the first time. A new technique that continuously assesses ability is sharing control between drivers and intelligent sensors. The work is improving access to independent mobility and allow at least some self-initiated mobility even without the spatial awareness and neural ability that is usually required, so that even some blind children are able to steer without needing helpers. The research is developing technologies that will enable the next generation of assistive devices to provide natural control through enhanced and intelligent sensor feedback. Choices for a particular driver are bespoke, based on their characteristics and history.

Overall aim of the work is to: **Create new systems to improve mobility and quality of life for people with disabilities**.

Objectives:

1: **Create AI to interpret what a human user wants to do**. This has reduced effort and stress. New digital object-proximity-sensing and some input devices have been created and simple systems to interpret them are being investigated. New Fuzzy Systems have been created to interpret hand movements and tremors from among other involuntary movements. Achieving this is allowing many more people to use powered wheelchairs.
2: **Sensor fusion to interpret the environment**. This is reducing tiredness and collisions. A Rule Based System generates revised instructions to correct for veer; the first time that this has been attempted. New digital object-proximity-sensing systems and effort-reduction systems have been created, along with new input devices and AI systems to monitor them. That is improving mobility and allowing some disabled people to use powered wheelchairs for the first time.

Proposal 16 submitted to 2021 IEEE International Intelligent Transportation Systems Conference (ITSC). Received February 13, 2021.

3: **Create a Decision-Making System (DMS)**. This compares outputs from the AI systems and suggests best possible courses of action. This is the only time that this sort of approach has been attempted with a powered wheelchair. Intelligent reasoning is providing confidence weightings to improve the DMS. Confidence weightings allow the DMS to efficiently select output. A Reasoning System is being used for this (and is currently being compared with other methods). Reasoning is being revised to compare errors against search criteria and then to investigate whether further improvement is possible. The system has been extended for this to investigate if results can be improved.
4: **Share control between the disabled driver and the new wheelchair system**. The ability of wheelchair users are being automatically assessed and control gains set for sensor systems and human drivers by calculating a self-reliance factor depending on ability, tiredness, recent driving performance etc. An avoidance-factor depends on obstacle proximity, a safety-factor denotes the ability of a driver and an assistance-factor depends on time spent driving and tiredness. The sensor system influences the motion of the wheelchair to compensate in those areas. This is the first time that a wheelchair system has adapted to a disabled human user in real time.

The six papers to be presented in the session are provisionally:

Navigation Assistance System using Sensors and Model-based Prediction. The development of a control system for an intelligent powered wheelchair is described. A navigation assistance system is a first step towards a higher level of automation and intelligence. The paper presents the generic components of the assistive system based on manoeuvre prediction. For derivation of the necessary functionality, the behaviour of experienced wheelchair drivers was analysed while they were driving their wheelchairs. Other aspects are discussed, including the precision of the models created from actuator and environmental data from sensors.

Steering a powered wheelchair using a camera module and an image processing algorithm. This paper presents a novel approach to steer a powered wheelchair using a camera module and an image processing algorithm. A circuit connected a camera with relays and a Raspberry Pi. A Python program is used to control the function of the camera and used the image processing algorithm to detect movement. The program is installed on to a Raspberry Pi and triggered the camera module to capture consecutive snapshots of the space in front of it. The camera was directed towards a user's body part and that body part was used to control the wheelchair. If the user moved their body part, the camera module detected that movement and the Raspberry Pi activated a wheelchair motor. "Sensitivity" and "Threshold" parameters could be modified in the Python program and were used to modify the sensitivity of the system for detecting movement and the amount of movement required to trigger the system. Practical testing showed the system behaved satisfactorily and detected users' voluntary movement. Clinical trials are being conducted at Chailey Heritage Foundation.

Driving a powered wheelchair using self-adapting switches requiring zero force to actuate them. A novel system for driving a powered wheelchair is presented. It uses self-adapting switches requiring zero force to actuate them. Switches 'self-adapt' to accommodate changes in position between sensors and operators. Zero force sensing is especially favored by disabled people with only small amounts of movement force available to them. Problems with existing switches concerns maintaining a suitable operating position for the user. These systems solve those problems. Testing the new adapting sensors has demonstrated their viability and optical sensors have provided a workable solution.

Demystifying Artificial Intelligence for Assistive Technology. This paper explains some of the key technologies concerned with Artificial Intelligence (AI), namely gesture recognition, speech recognition, expert systems, machine learning and related techniques. The intention is to give an introduction for laymen illustrating each technique with assistive mobility examples. Finally the paper discusses some limitations of AI for assistive technology.

Situation Awareness and Obstacle Avoidance. Situational awareness and obstacle avoidance are considered for a powered wheelchair. Higher level route planning and image processing algorithms are considered and used for obstacle detection. A voter based control system uses the results.

Using Image Processing Algorithms to Drive a Powered Wheelchair. This paper presents a new system that uses an image processing algorithm to drive a powered wheelchair. Powered wheelchair drivers generate a voluntary movement and the new system senses that movement and translates it into driving commands to drive a powered wheelchair. Python programming language is used to create a program that controls the function of the camera, Raspberry Pi and relay circuit. The program is installed onto the Raspberry Pi. The camera was placed in front of a user body part used for controlling a wheelchair. If the user made a movement, the camera sensed that movement and the Raspberry Pi sent a trigger signal to a specific relay for operating a wheelchair motor. Two User Interfaces were created to operate the new system and adjust its sensitivity. Practical testing showed the system successfully detected users' voluntary movements and translated that movement to driving commands to drive a powered wheelchair. Clinical trials are being conducted at the Chailey Heritage Foundation..

The importance of the session in simple terms.

The session will focus on the novel use of sensors and new shared control systems and AI to significantly and positively impact on the lives of powered-wheelchair users. The most recent developments and creations will be presented

Recently developed sensors have been digitised, and then used in novel ways with AI to assist with driving powered wheelchairs. This is allowing some people to use a wheelchair by themselves for the first time, and is making driving and steering easier for many others. That is reducing the need for carers, improving health outcomes and giving disabled people an opportunity for more independent mobility. For some it has provided mobility for the first time.

Access to independent mobility is important for self-esteem and a feeling of wellbeing. Natural independent mobility such as crawling and walking are usually acquired in the first two years of life; if this does not happen then people can find it difficult to acquire the skills later. Currently a wheelchair can provide some self-initiated mobility but it cannot be introduced unless a person has the spatial awareness, physical ability and cognitive skills to understand the concept. Being able to transport oneself has a positive effect on general development that cannot be underestimated. This research is providing that opportunity.

Research at the University of Portsmouth has already resulted in analogue collision avoidance and effort-reduction systems, so that people can drive for longer. Work at the Chailey Heritage Foundation created track systems to guide wheelchairs and novel systems that can follow a path parallel to a wall and sensors to safely detect the environment. All the devices are being redesigned as digital systems to connect them to expert systems for improved control. The new digital versions are interfacing to microcomputers. The new systems are interpreting hand (or body part) movements and tremors to improve control further. That is allowing users to steer their powered wheelchairs without needing helpers and providing a greater sense of accomplishment and freedom, whilst simultaneously helping to reduce carer costs.

The abilities of the wheelchair user are being constantly assessed so that control gains can be automatically set for the sensor systems and the human driver. This is being achieved by calculating a self-reliance factor depending on ability, tiredness, recent driving performance etc. An intelligent avoidance-factor depends on obstacle proximity, a safety-factor denotes the ability of the driver and an assistance-factor depends on time spent driving and tiredness. The sensor system influences the motion of the wheelchair to compensate in those areas. This is the first time that this has been attempted.

Different AI systems are being used for different tasks to capitalise on their separate distinct strengths in diverse circumstances. An original hierarchy based upon the structure of Artificial Neural Networks has been used to integrate them. Up to three AI techniques are being used at any one time to select courses of action for a wheelchair and a new Decision Making System (DMS) determines a best course of action by considering and comparing the outputs from the different artificial systems and the requirements of the human user. Each system provides a level of confidence for a potential course of action, for example turn left, stop etc. The DMS will determine the action to take.

This work is producing both new devices and new ways of integrating devices into wheelchairs to ensure safe navigation and personalized assistance with general low cost but automatically adjustable solutions that make the systems bespoke and adaptable in real time. This is helping to ensure users achieve maximum functionality. The devices can be added to existing wheelchairs, providing a cost-effective way of improving quality of life and independence.

Impact

Research is benefiting people with Multiple-sclerosis, Arthritis, Stroke, Paraplegia, Orthopedic-impairment, Cerebral-palsy and Diabetes, especially if blind or with missing or damaged-limb(s). Disabled community groups, carers, users and families who have used the analogue systems are adopting the new systems. They and their families are keen to hear about the research and are engaging; they are keen to give opinions to guide research.

Health. Work is directly benefiting disabled users and their quality of life is being enhanced. New systems are allowing people with limited dexterity to use wheelchairs; users are driving for longer and more safely. The digital and AI systems led to new, faster and more responsive processes that replaced some older systems in schools and institutions, hence further improving lives. It has made a significant positive difference by giving disabled individuals more confidence, independence and freedom, especially people with limited spatial awareness or cognitive ability. The techniques are also contributing to the digital component of the European Research Digital Economy Programme, involving real-time data fusion and patient tracking.

Professional services. Professional UK guidelines and training are being informed by the research, and new technical standards and clinical protocols are being introduced. The new systems will are prompting changes to professional practices in that powered-wheelchairs are being considered as an option, even for blind children, and new technical standards and clinical protocols are being introduced. Health outcomes are improving because of the new systems and the work is leading to new methodologies for therapists to teach people how to drive.

Cost Reduction. The research has introduced some autonomy and reduced the need for carers. Further, the costs of the systems are reducing due to digitization. Health outcomes are being further improved because of the availability of the new systems and the new ways that people will be trained on them, and improvements to mental health and wellbeing will reduce NHS costs.

Schools, health services, and institutions. Beneficiaries are gaining directly through links to CHF and other institutions; time between discovery, research and use is being shortened as new theoretical knowledge and systems are being passed to CHF for testing, use and immediate impact. Systems are being quickly proved in schools where they have an immediate beneficial effect. With the help of CHF, they will quickly move on to be used by health systems, disabled community groups, private homes and by individuals. This project will also provide predictive tools to determine system use over time. That will support clinicians to assess intervention needs. Developing such techniques and technology is of key interest to powered wheelchair specialists in the medical and healthcare industries.

Industry. Wheelchair manufacturers have access to the new systems and they can easily be added to existing wheelchairs. Software companies have access to the new software. The world is short of rehabilitation engineers and this project is helping address that by producing more postdocs working in rehabilitation technology. Car manufacturers have access to the new technology for driverless vehicle research. The work has been of use to wheelchair manufacturers but is also of interest to the defence and automotive industries (tracking, driving, navigation) and any innovation in this field is being quickly adopted. Research in sensor fusion and AI is feeding forward (and across) to companies who are developing automotive software and sensors, and who want to deploy self-driving cars.