Project report: **Assessing and improving mobility of wheelchair users**

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Summary
There are around 1.2 million wheelchair users in the UK and many of them have limited access to social- and health-care due to limited mobility and increasing pressures on the NHS. A possible motivation for wheelchair users to keep fit is to introduce suitable mobility tracking technologies. Compared to walking-trackers there are almost no feasible solutions for wheelchair users. Providing mobility tracking technology for wheelchair users to improve the awareness of their daily physical activities would motivate them to move more, exercise more and ultimately lead to being more fit and healthy. This project was conducted in 2018-19 in close collaboration between the Centre for Advanced Robotics and the Centre for Sports & Exercise Medicine at Queen Mary University of London (QMUL).

Objectives
Objectives of the project were:
- to suggest mobility indicators and activity tracking methods for wheelchair users;
- to design, build and test an on-board, low-cost, mobility tracking module for wheelchairs;
- to develop and test a smartphone application to collect, display and analyse mobility tracking data from the wheelchair.

Outcomes
We have designed and manufactured a mobility tracking module which can be easily integrated with any type of wheelchair. The module, shown on the figure below, integrates various sensors (wheel encoders, inertial units, GPS, environmental sensors), microcontroller and communication modules, and a battery unit. The data from the sensors is sent wirelessly to a smartphone application developed during the project to compute and graphically represent mobility data. An example of the graphical user interface of the developed app is shown below. The overall system was presented to several wheelchair users and has received positive feedback. Wheelchair users have confirmed that they would be happy to use such a system and have proposed several improvements. Among them are hardware module minimisation; adaptation to complete wireless sensing; removal of encoders for contact-based wheel rotation sensing; and adding energy consumption activity indicator to the

smartphone application. Following these feedback, we have performed an experimental study to map the physical activity of the users during active wheelchair movements to the actual energy consumption using motion tracking, upper body muscle activation and respiratory measurement techniques. It was discovered that it is possible to use a scalable generic model for physical activity energy estimation of a wheelchair user combining simple upper body (arms and trunk) and wheelchair movement (acceleration, speed and inclination). The upper body movement can be measured with a smartphone's accelerometers which can be worn on the trunk or one of the shoulders while the wheelchair movement data can be received from the developed mobility tracking module.

Dissemination

The system testing was performed in cooperation with AbilityBow; a physical disability sports and exercising charity in east London. Project demonstrations for general public and industry were organised at the following events: seminar at KoreaTech University invited talk (8/03/19), QMUL Industry day (24/04/19), QMUL Strategy 2030 event (2/05/19), Festival of Communities (15-16/06/19) and several robotics lab demonstrations. The system developed was awarded the Best Software and the Best Hardware student projects of the School of Electronic Engineering and Computer Science (top 1%). Two research articles are in preparation to describe the technology and its biomechanical validation.

The video on the project can be seen here https://www.youtube.com/watch?v=zrIrmkv1tJg

Future development

The results of the user studies and biomechanical experiments suggested that the proposed wheelchair mobility tracking technology can be improved by adding a wearable wrist acceleration sensing device. Currently, we are developing a second prototype which will integrate wrist movement measurement with the smartphone app and the wheelchair's acceleration sensors. Applications for further funding have been submitted to improve the functionality and robustness of the tracking module. We believe that such an activity tracking system would be useful for a wider range of mobility assistive devices.