Exploring computer vision as a platform to deliver playful home-based manual wheelchair skills training

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Summary
We adapt computer vision technologies to explore the potential of an interactive tool to support manual wheelchair skills training. We explore the general feasibility of the technology through case studies implementing computer vision in wheelchair-controlled video games. Our work opens up avenues for accessible and affordable wheelchair skills training.

Aims and Objectives
Our first objective is to establish the feasibility of widely accessible computer vision technologies in the context of interactive wheelchair skills training. This includes the development of a camera-based tracking system to translate wheelchair and body movement into computer input. Secondly, we leverage a set of wheelchair-controlled games as a test bed to study the practicability of vision-based wheelchair tracking with two groups of wheelchair users, older adults and children.

Background
There is a limited accessibility of wheelchair skills training across the UK [4], which reduces the independence of people with mobility impairments. This does not only profoundly impact the quality of life of wheelchair users [3], but it additionally leads to medical conditions that result from a lack of activity and participation [1], whilst increasing financial pressure on healthcare systems. Previous work provide computer-based wheelchair skills training for powered wheelchairs in simulated virtual environments (e.g., [1], [2]), however the provision of manual wheelchair skills training remains a challenging task and requires further research. In our work, we explore computer vision and camera-based computer interaction as a means of providing home-based wheelchair skills training. This abstract reports on two case studies [5, 6], that explore the feasibility of camera-based interaction in a playful setting. Building on these results, we outline challenges and opportunities in the use of computer vision as a means of providing manual wheelchair skills.

Technique: Microsoft's Kinect is a widely available device using an RGB camera and infrared depth sensors that provide a full-body 3D motion capture and gesture recognition system. We use these computer vision powered sensors. We record natural body gestures to enable us to infer wheelchair position and movement, building on a skeletal tracking approach to provide information on the posture of the user. This lends itself to future evaluation of movement accuracy in the context of occupational therapy. Our current toolkit integrates basic wheelchair movement (e.g. moving back and forth, turning to the sides) along with upper body movement of the user.

Case studies:
(1) Wheelchair-controlled interactive systems for older adults and (2) Wheelchair-controlled Exergames (exercise games) for children.
The first case study [5] explores the use of wheelchair-controlled game input through the development and evaluation of Cupcake Heaven, a video game in which players control a digital character by moving their wheelchair back and forth, whilst raising their arm to collect candy displayed in the game. A mixed-methods evaluation with ten older adults who use wheelchairs on a daily basis demonstrates the general feasibility of the input mode in terms of responsiveness and tracking accuracy; additional qualitative participant feedback highlighted the engaging nature of

interactive content. In the second case study [6], we evaluate the appeal of Skiing Mountain and Collector of Light, two video games in which wheelchair movement (turning and moving back and forth) controls a character that continuously moves through a virtual world. Qualitative feedback from five children and four carers showed the games were generally accessible, and regarded as an opportunity to encourage physical activity.

Discussion

The two case studies demonstrate the feasibility of computer vision as a means of tracking basic wheelchair and body movement to open up avenues for the development of interactive wheelchair skills training. Most importantly, they show the general accessibility of wheelchair-controlled computer input for diverse audiences, and highlight the potential of using interactive systems as a means of encouraging and guiding user movement. In terms of technical challenges that would arise in the context of skills training, the current approach needs to be refined to offer detailed user feedback on movement accuracy, along with the integration of sequential movement relevant to skills training. To address this challenge, we are currently working on an RCUK-funded research project to develop our system into a platform for home-based interactive wheelchair skills training.

Building on our existing toolkit, we are expanding the system to record and store user actions into a dataset that consists of sequences of movement, represented as body-part locations and the associated wheelchair movement. It will be integrated into an interactive training application in which users can exercises in their own home. Wheelchair skills will be translated into an animated on-screen character; to build and improve wheelchair skills, the user can place themselves within the Kinect's field of vision and follow on-screen instructions. The system captures movement in real-time, and comprehends body movements by comparing them with the database. Leveraging this information, the resulting system will be able to provide feedback on movement accuracy, and make recommendations for improvement.

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