User-Centered Development of a Human-Machine Interface for Robot-Assisted Daily-Living Activities of Tetraplegics

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Introduction

Tetraplegia is a condition that affects the sensory and motor functions of the upper and lower extremities as well as the trunk. Most tetraplegics have no proper function of the upper extremities, making it very difficult to perform activities of daily living [1]. A possibility to improve the quality of life is a wheelchair-mounted assistive robot. The goal of this thesis was to develop a human-machine interface (HMI) for tetraplegics to help them perform activities of daily living with an assistive robot.

Materials and Methods

Fig. 1 shows the test system. An iterative, user-centered design process was used to develop the HMI. Literature reviews and user research in the form of interviews and home visits were conducted to understand the needs of tetraplegics and decide what type of HMI would be most useful. Several iterations of the HMI were developed and evaluated by two tetraplegics and ten able-bodied persons. The following quantitative evaluation methods were used: Raw Task Load Index [2], System Usability Scale [3], task completion success, and duration. In addition, usage monitoring and open-ended questions were used as qualitative measures.

Fig. 1: Test system. (A) electric wheelchair, (B) robot arm, (C) control electronics, (D) tablet, (E) head pressable stop switch. Components (D&E) are most relevant for this thesis.

Results

Interviews with four tetraplegics concluded that a graphical user interface (GUI) is the preferred type of HMI. However, the GUI must be operatable by touch, joystick, or speech. The final HMI (Fig. 2), allows controlling every motion of the robot arm, save robot poses, and automatically grab objects if they are detected by the robot's camera. The evaluation results of the third and final design iteration presented as box plots can be found in Fig. 3.

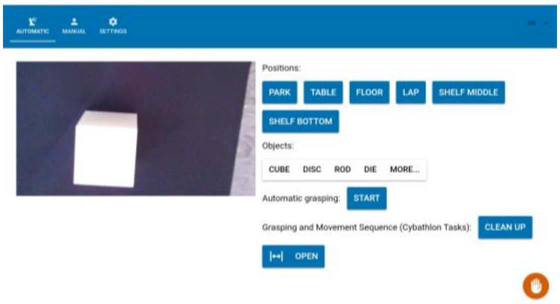

Fig. 2: Final web-based HMI

Discussion

The evaluation demonstrated that the HMI can be operated by tetraplegics. All targets were achieved except for frustration, which can be attributed to occasional long reaction-times of the prototype system. The system is in undergoing development and the HMI will be adapted accordingly. This thesis focuses on tetraplegics, but people affected by strokes or amyotrophic lateral sclerosis can also benefit from assistive robots and an intuitive HMI.

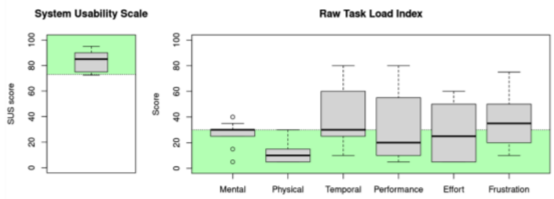

Fig. 3: Results of the third and final evaluation. Ten able-bodied subjects tested the HMI. The green area is the target usability and task load level.

References

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