THE ROLE OF ROBOTICS IN THE DESIGN OF DEVICES TO ASSIST PERSONS WITH DISABILITIES

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Introduction

An assistive technology device is defined as "any item, piece of equipment or product system whether acquired commercially, off the shelf, modified, or customized that is used to increase, maintain or improve functional capabilities of individuals with disabilities" [1]. Disabilities occur throughout the entire age spectrum and the incidence of disability increases with age. In developed counties, increased life expectancy will result in a greater need for effective assistive devices. The use of robotic devices holds great promise to enable persons with disabilities to achieve/maintain their functional independence particularly in areas associated with daily living activities. As with other applications, safety is paramount. Robotic assistive devices can be divided into two categories;

1. Autonomous robots that entirely replace, or nearly replace, the human function. The design process for these robots does not differ substantially from other applications. Sensors, objective functions and effectors are used to construct closed loop controllers. The goals of these controllers are to optimize some measurable set of performance variables.

2. Robotic devices that share functionality with the user and are closely coupled to that individual's abilities. In contrast, the design of these assistive devices is user centered and his/her abilities are an integral part of the design. Typically the user possesses some of the sensory and effector functions and some cognitive ability to form objective functions. The design process for these robotic assistive devices encompasses a much wider range of design parameters that other robot applications.

The purpose of this paper is to highlight the unique features of the design process for human-centered robotic assistive devices and to use case studies to demonstrate some of these features.

Human-Centered Design Process

The Human Activity Assistive Technology (HAAT) model is a commonly used framework for developing assistive devices [2]. This model is based upon a human desiring to perform an activity within a specific context using assistive technology. The model recognizes two important features of the design process;

1. The critical role of proper design of the user/technology interface. This interface must be designed to accommodate the needs, capabilities and desires of the user.

Qualitative issues such as aesthetics and "feel" can lead to user rejection of otherwise superior devices.

2. The importance of context related issues such as setting, social environment, cultural factors and physical conditions including lighting and sound level.

Successful completion of an activity requires that a person possess the minimum set of performance resources that are necessary to perform the task [3]. For example, drinking from a cup requires a large number of physical and cognitive performance resources such as targeting, ranges of motion, strengths, steadiness, etc. Lack of a single required performance resource will prevent successful completion of the activity. A key consideration in the design of robotic assistive devices is the proper allocation of function between the human and the device. One approach is leftover allocation which assigns as many functions as possible to the human and the remainder to the device. Another approach is flexible allocation which allows the user to vary his/her participation in the activity. This latter approach is particularly important when the level of disability is expected to change with time.

Case Studies

The following case studies illustrate some of the factors that must be considered in the design of human-centered robotic assistive devices.

Reacher/Gripper Device. A 9 year old girl with arthrogryposis used a powered wheelchair and, due to her extremely low grip strength, frequently dropped personal objects such as pencils, paper and hairbrushes. She lacked the ability to use mechanical reacher/grippers to transport objects from ground level back to within her reach. Solving this problem using a robotic arm attached to her wheelchair would normally require the device to have 4 degrees of freedom (DOF) (planar positioning (x, y), grasping and elevation angle). Careful client evaluation revealed that she had excellent wheelchair planar positioning skills, thereby eliminating the need for 2 DOF in the robot arm [4].

Backpack Access Device. Power wheelchair users often transport their personal items in a backpack which is suspended behind the wheelchair from the headrest. In this location, the user requires assistance to retrieve items. A one DOF robotic arm based upon a four bar linkage was designed for a 13 year old female student with cerebral palsy. When activated, the mechanism extended as it rotated from its storage position behind the wheelchair to deliver the backpack to the right front side where she could independently access its contents. She successfully used the device for 3 months until a minor drive component failed. She requested that the device not be repaired as she had become self conscious about the aesthetics of having the device mounted on her wheelchair.

Discussion

The design of human-centered robotic assistive devices involves additional, unique, quantitative and qualitative design parameters that are not present in other robot applications. User acceptance is based upon a broad range of criteria that extend well beyond technical performance. Just as these devices are human-centered, the design process must also be user-centered. It is critical to incorporate focus groups of potential users at the beginning of the design process and keep them fully engaged throughout the process. The user/technology interface is of critical importance with some suggesting that it should be considered a separate independent design activity that is conducted in parallel with the technical design of the device.

References

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