Using Supernumerary Robotic Arms for Background Tasks

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ABSTRACT

Numerous studies have envisioned the explicit and implicit use of Supernumerary Robotic Limbs (SRLs), wearable robotic limbs, to directly assist a user in performing tasks. In this paper, we explore in which situations Supernumerary Robotic Arms (SRAs) could be used in to perform background activities. We conducted a preliminary design study to better understand user expectations for using SRAs in background tasks. Our results highlight that SRAs can be helpful in performing background tasks alongside users performing a primary task. Informed by our study we present our current implementation efforts and suggest directions for future work.

Keywords: Supernumerary robotic limbs, human-robotic interaction, background activity

Index Terms: H.5.2. [Information Interfaces and Presentation]: User Interfaces

1 INTRODUCTION

The notion of cyborgs, "part human, part machine" entities, is beginning to move from the literary world to the physical one. Disabled individuals with prosthetic limbs is a real-world example of today's cyborgs [1]. Research has revealed that prosthetic limbs have significant potential to positively impact quality of life and daily usage. For example, a commercial wheelchair arm JACO developed by Kinova [1,2], although not biologically infused with the user, can help users with activities of daily living.

In response to these findings, many research projects have proposed and prototyped Supernumerary Robotic Limbs (SRLs), a human-wearable, yet detachable system composed of mechanical limbs capable of augmenting the user's physical capabilities [3-8]. Using SRLs, humans can learn to adapt to a cyborg mentality without the commitment of changing their physiological structure to do so. SRLs offer some of the same advantages as their biological counterparts: examples include bearing physical loads borne by the user and helping the user with grasping objects [4,6,8].

Previous studies have highlighted various instances where SRLs could be used for primary tasks, namely in medicine and manual labor. However, very few of these studies have actually generalized to the use of SRLs in background activities. Our overarching long-term goal is to explore the types of tasks SRLs can help with, and how a user controls these limbs to carry out a task. Based on the examples presented in literature [3-6], we posit that SRLs can help with two types of activities – primary and background tasks – and within these activities, SRLs can be controlled either explicitly or implicitly. Primary tasks are often the focus of the user. Background tasks are not the focus of the individual but are still supplementary to the main activity. For example, in construction work, building an artifact is the primary task and handing someone tools is a background task.

In this work-in-progress project, we propose to explore the use of implicitly controlled SRAs for performing background tasks. We imagine that humans might prefer to carry out primary tasks themselves. As a result, SRAs may be beneficial for performing background tasks supplementary to the user's primary task. In the remainder of the paper, we present the current state-of-the-art research in this realm, and then present our exploration and findings of possible background tasks that SRAs could perform to augment primary tasks.

2 RELATED WORK

Several researchers have explored the use of SRLs for specific applications. For example, physical rehabilitation has motivated the construction of self-learning and user-controlled Supernumerary Robotic Fingers, devices meant to assist humans in primary activities such as grasping objects [6,8]. These extensions of the human hand have enhanced basic grasping behaviours, what some researchers consider the most fundamental functional requirement for manipulation [6].

It is clear that SR Fingers can be quite useful in accomplishing primary tasks but having SRLs execute background tasks can be equally beneficial. One study conducted with human participants explored how SRLs can be useful in performing a coordination-based task; in this case, stabilizing a workpiece as a construction worker drilled into it [3]. Another design concentrated on a bracing strategy used by SRLs to reduce static loads borne by users completing physically demanding tasks [4]. While both of these cases underline the effectiveness of SRAs in supporting users as they focus on a primary task, the SRAs were only simulated by two human actors and have yet to be implemented.

A few studies have managed to produce SRL prototypes capable of assisting humans with both primary and background activities. Sasaki et al. experimented with the adaptation of humans to "MetaLimbs," SRAs whose function was explicitly mapped to the human foot [5]. In a series of tests, participants learned to use robotic arms for both primary and background tasks ranging from grasping cups to picking up phone calls while typing [5]. A mechanical hand augmentation device was developed by Leigh and Maes for the purpose of studying "synergistic interaction" [8]. Their device assisted users in performing two-hand operations using a single augmented human hand.

This project builds on and adds to the current body of work by exploring the use of SRLs from a unique perspective. Unlike earlier studies, the goal is not to create a new design for SRLs but to examine the interactions between humans and implicitly functional SRLs used in background activities. It focuses on a larger scale than just hand augmentation devices, specifically robotic arms, which can move more independently of the user's movements.

3 PRELIMINARY DESIGN STUDY

We conducted a preliminary design study to research what users would expect from additional robotic arms for performing background activities. For this study, to familiarize the

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participants with the idea of SRLs and background activities, we selected a few simple activities such as a colouring task and a selfie-taking task as starting points. We chose these tasks as they clearly demonstrated implicit control of the SRAs.

Figure 1: Design study tasks with simulated SRAs.

Similar to the methodology used by [3], we conducted our preliminary study using human actors. Our preliminary study involved three pairs of human participants. From each pair, one would simulate the SRA and the other would be the end-user. Having both roles played by humans provides insight on two important perspectives: how participants imagine SRAs would work around the user, and how the user would perform an activity in collaboration with SRAs.

Participants first took part in the colouring task (Figure 1a). The taller of the two participants would act as an SRA and the shorter of the two would be the human user. The user was instructed to draw five objects they would find in a home. Once the user had completed a drawing, the participant simulating the SRA would colour in the drawing using pencil crayons.

The second was a selfie task, where each participant had the opportunity to be both the SRA and the human user (Figure 1b). In this situation, the user held up the artwork from the previous task while the arms, handling a selfie-stick with a smartphone attached to the end, took pictures of the user from different angles.

Each pair shared feedback of their experience in a post-study interview. We also asked participants to reflect on other potential background tasks that SRLs can help with. The audio and video recordings of participant responses were transcribed and the similarities and differences between the responses were noted.

We observed a few recurring patterns among the responses from the participants. They agreed that SRAs could be helpful in parallelizing tasks, although there were varying opinions on the types of tasks SRAs should help with. Some imagined that SRAs would only be useful when supporting users with complex tasks normally requiring more than two hands, for example in construction work. Others wanted to use them for simple, mundane tasks like cleaning. They also thought that implicitly functional SRAs should be able to understand and act according to the user's intentions, while not interfering with the user's own work. While they were comfortable with implicit control, several participants also wanted some degree of explicit control over the robotic arms. In terms of the physical design, participants expected SRAs to be easily detachable and easy to store when not in use. Of the two design study tasks, participants felt that SRAs interfered less and were more helpful in the selfie task. Thus, we decided on replicating the selfie experiment for the main study.

4 CURRENT PROTOTYPE SYSTEM

Informed by our study, going forward, our proposed implementation incorporates a similar selfie-taking task. A participant is introduced to Baxter, a humanoid robot whose right arm will act as SRAs throughout the experiment as depicted in Figure 2. Attached to Baxter's right arm is a selfie-stick with a smartphone hooked onto the end. Attached to the robot's core are backpack straps so that the user can simulate the experience of "wearing SRAs".

Figure 2: Selfie task with Baxter robot acting as SRAs.

The participant will pose holding an object of choice with both hands. An audio file will be played before taking a picture, to notify the user of the robot's intended action. The right arm will move based on a timer (rather than explicit user commands) to vary the angle of the camera and take selfie pictures.

5 CONCLUSION

In this paper, we explored human-robotic interaction between humans and SRLs performing background activities. From our preliminary design study, we found that individuals preferred using implicitly functional SRAs for background tasks. Going forward, we plan to improve our implementation wherein the implicit behavior of the SRA is based on specific cues such as body movement of the user, and facial expressions. We also want to incorporate a more elaborate "vlogging" experiment wherein the robot takes short videos of the participant crafting art. Using the more thorough implementations, we plan to conduct further user studies to determine the usability, effectiveness, and desirability of the SRAs for background tasks.

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