Supernumerary Arms for Gestural Communication

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Abstract
Cyborgs are human-machine hybrids with organic and mechatronic body parts. Like humans, cyborgs may use their additional body parts for physical tasks and communication. In this study, we investigate how additional arms can be used to communicate. While using additional arms to perform physical tasks has been researched, using them to communicate is an area that is largely unexplored. Our study is divided into three stages: a pilot study, implementation, and a user study. In this paper, we discuss our efforts as related to the first two stages of our study. The pilot study was used to determine user expectations for the arms. Participants found the arms effective for describing an area from a fixed location. Users also preferred additional arms that can be controlled and are physically similar to their existing arms. Our prototype consists of a virtual mirror that augments the user's body with additional arms. We discuss future directions for improving our implementation and outline a plan for the user study.

Author Keywords
Gestural communication; Virtually augmented bodies; Cyborgs;

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces

Introduction

Cyborgs are humans that have replaced or enhanced their natural capabilities with the help of machines. While the idea is commonly associated with science fiction, medical devices such as cochlear implants, pacemakers, and artificial limbs have transformed their users into what may be considered a cyborg.

Cyborgs are not just limited to modified or replaced body parts; they may also have additional body parts such as an additional pair of arms. What could these additional arms do? Current research primarily focuses on how humans may be able to use additional limbs, including arms, to perform physical tasks [3-6]. However, our arms can also be used for communication. Goldin-Meadow (Goldin-Meadow, 1999) describes two ways hand/arm gestures can be used to communicate. First, gestures allow the speaker to convey ideas that cannot be effectively communicated using speech such as shapes, sizes, and spatial relationships. Second, gesture frees up cognitive resources for speakers. If our arms can be used for communication, perhaps additional arms could be used in the same way.

In this paper we explore how additional arms can be used for communication. We divide our investigation into three steps. First, we will conduct a pilot study to better understand user expectations for additional arms. Second, we will use ideas gathered from the pilot study to develop a virtual prototype of the additional arms. Third, we will conduct a user study to evaluate how effective the arms in our prototype are for communication. This study will contribute to a growing body of knowledge on augmented bodies and gestural communication.

Related Work

Researchers have shown that gestures can affect the perceived personality of a virtual agent [2]. In this study, researchers used an open ended and standardized questionnaire to survey how participants perceive the personality of a virtual agent. In one experiment, participants were shown a video of one of two agents. The first agent was an intended extroverted agent whose gestures were faster, larger, and located further away from the body’s centerline. The second agent was an intended introverted agent whose gestures were slower, narrower, and located lower on the torso. Researchers found that both methods of evaluation suggested that participants perceived the intended extroverted agent as extroverted. However, the same methods found that the intended introverted agent was perceived as neutral rather than introverted.

In another study, researchers have evaluated the impact of gestures on perceived workload [4]. The researchers developed a memory game to be played using the Nao robot. The robot issued a set of directions that participants were asked to remember. This was done with and without gestures and for easy and difficult directions. Researchers found that there was a decrease in perceived workload when the robot gestured compared to when the robot did not gesture. However, this was only true when the objective workload was high (difficult directions). When the objective workload was low, there was no significant difference in perceived workload between the gesturing and non-gesturing cases.

Our work is inspired by these projects and explores how people can use additional arms to communicate.

Pilot Study

We first conducted a pilot study to determine user expectations for using bodies augmented with additional arms. In the pilot study, three pairs of participants were recruited to simulate a person with additional arms. One participant acted as the speaker while the other participant acted as the additional arms. We will refer to the speaker as the *speaker* and the participant acting as the additional arms as the *arm actor*. The participants were given three communicative tasks that commonly use verbal description and hand/arm gestures. The three tasks were as follows:

1. Describe a picture of a room
2. Given a picture of a maze, give directions to navigate the maze
3. Give directions from one location on the university to another location

For each task, the investigator acted as the listener and was assumed to have no knowledge of the room, maze, or directions around the university. After each task, participants swapped roles and performed the same task again (with different pictures/locations) before moving on to the next task.

Description of Tasks

ROOM DESCRIPTION

The speaker was given a picture of a furnished room. They were asked to describe the room as accurately as possible. At no point was the arm actor able to see the picture.

MAZE NAVIGATION

The speaker was given a picture of a simple maze with the correct path drawn. They were asked to describe how to traverse the maze. At no point was the arm actor able to see the picture.

UNIVERSITY NAVIGATION

The speaker was given two locations on campus and asked to give directions from one location to the other. The locations were chosen so that the arm actor also knew how to get from one location to the other. The arm actor and speaker did not discuss the directions they had in mind.

Modes of Control

The above procedure was completed twice by each pair of participants, once with implicit arm control and once with explicit arm control.

In the implicit control case, we test how additional arms could be used without any direct input from the speaker. The arm actor was asked to stand behind the speaker and place their hands wherever they felt was best for communication. Participants were instructed not to communicate with each other directly.

In the explicit control case, we examine how additional arms could be used when the speaker has complete control over the additional arms. The setup is identical to the implicit control case except the speaker and arm actor were allowed to interact directly.

Results – Implicit Arm Control

ROOM DESCRIPTION

Most speakers actively gestured throughout their description of the room. The gestures primarily consisted of pointing to indicate the position of objects, and hand movement to describe the shape of objects.

Figure 1: Arm actor mimicking the speaker

Figure 2: Arm actor describing the shape of a brick with their hands

While most arm actors also gestured, most simply mimicked the speaker's gestures. Arm actors commented that because they did not know how the room looked, they did not know how to assist the speaker. To prevent confusion, they mimicked the speaker or did not gesture at all. Only one arm actor gestured in a way that did not mimic the speaker. In this case, the arm actor attempted to build a frame of reference to help the speaker; they used their arm to mark the location of a cabinet in the room so that the speaker could describe object locations using the cabinet as a visual frame of reference. After establishing the location of the cabinet, the arm actor did not make any additional gestures.

MAZE NAVIGATION

Most speakers gestured when describing how to navigate the maze. These gestures primarily consisted of simple pointing gestures to describe directions (left, right, etc.) and creating a 'T' or 'X' with the hands to visually describe three and four-way intersections.

While most arm actors also gestured, all mimicked the speaker's gestures. Speakers and arm actors both felt that because the gestures were simple, additional arms would not be helpful. As was the case with the room description, arm actors felt that since they could not see the picture, they were not able to assist the speaker.

UNIVERSITY NAVIGATION

Most speakers gestured in this navigation task. The gestures consisted of pointing gestures to describe directions and the location of landmarks and hand movement to describe the shape of physical landmarks. Despite gesturing, some speakers felt that gesturing was not helpful when describing long distances where one's frame of reference constantly changes.

In this task, all arm actors gestured. While mimicking gestures were also observed, there were more "useful" gestures than in the room description and maze navigation. Since the speaker and arm actor had a shared knowledge base, the arm actor was often able to gesture without having to wait for the speaker to finish an idea. However, this also created multiple instances where the arm actor's gestures conflicted with what the speaker was saying. In one instance, the speaker and arm actor had slight differences in routes in mind which caused a gesture-speech conflict. In a second instance, the arm actor and speaker had the same route in mind, but the arm actor gestured before the speaker vocalized the corresponding words. This briefly confused the speaker.

Results - Explicit Arm Control

ROOM DESCRIPTION

Speakers actively moved the arm actor's arms to establish points of reference. In most cases, the additional arms were used to locate a single object which the speaker referred to when describing the location of other objects. In one case, the arm actor attempted to construct a visual representation of the walls of the room using their, allowing the speaker to place objects within these "walls". While speakers were unsure if these actions were helpful for the listener, they felt it helped them understand their own explanation

MAZE NAVIGATION

Four of six speakers used the additional arms to form the halls of the maze while using their own hands to act

Figure 3: Speaker using additional arms to represent the walls of a maze

Figure 4: Speaker using additional arms as a reference point (book shelf)

as the person in the maze. Surprisingly, three of these speakers found moving the additional arms was a hindrance to communication. They found that having to readjust the "walls" was often distracting.

UNIVERSITY NAVIGATION

The results of the university navigation were similar to the maze navigation. While speakers gestured, they found that constantly moving the additional arms was distracting.

Results - General Feedback

When asked about whether the additional arms were helpful in the implicit case, all speakers responded that they generally did not pay attention to what the arm actor was doing; they were more focused on themselves. Speakers found that mismatches between their words and arm actor's gestures often lead to confusion.

Despite not finding the arms generally useful when implicitly controlled, speakers felt like the arms would have been useful if they could be explicitly controlled. Several speakers wanted to use extra arms to communicate spatial information such as the location of an object or the size of a hallway. However, because the arm actors did not have the speakers' knowledge, they were unable to do this. Additionally, some speakers wanted to control the arms because they feared the arms' independent action or wanted to avoid a speech-gesture mismatch.

All participants wanted the additional arms to extend from an area close to their shoulders. Two participants wanted them above the shoulders to maximize upward mobility and to minimize discomfort when resting one's natural arms. The remaining participants wanted them under their arms so that the additional arms could perform the same actions as their natural arms. Participants preferred the additional arms to resemble their own in size and shape. However, they wanted the arm to appear clearly artificial, as a realistic arm would be "too creepy".

Virtual Prototype

Drawing ideas from the pilot study, we created a virtual prototype of a pair of additional arms. The key features are as follows: the additional arms will be controlled directly by the user and originate at the shoulders. Using the Microsoft Kinect, we created a virtual mirror where two arms are rendered onto the user's body.

The arms consist of two parts: a controller (brown cubes) and a skeleton (white lines). To move an arm, the user places their hand behind the controller and forms a closed fist. While the user's hand remains closed, the additional arms will move with the user's arms. To lock an arm in its current position, the user simply opens their hand. We find these actions intuitive because it resembles holding and releasing a physical arm.

Current Limitations

The current prototype has several limitations that we are currently trying to address. Firstly, the skeleton is 2D in nature. While this is not a significant problem when the arms are in the same plane as the body, it becomes a problem when the arms extend towards the camera. With 2D lines, there is a limited sense of depth and it is hard to recognize that the arms are pointing towards the camera. Finally, the controllers are relatively primitive, consisting of only a brown cube.

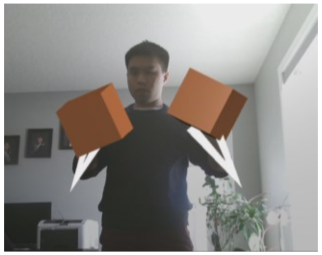

Figure 5: Initial position of additional arms

Figure 6: New position of additional arms

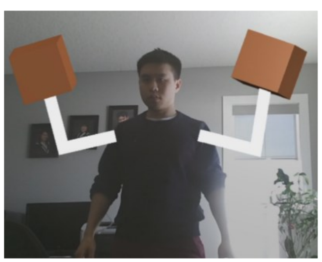

Figure 7: Additional arms locked

Creating a controller similar to a hand with fingers will allow for a greater range of expression. Once these limitations have been addressed, we will be able to move onto our user study.

User Study

Our user study will evaluate the effectiveness of additional arms for describing special information from a fixed location. This is the scenario that participants in the pilot study felt additional arms would be most useful. In the user study, participants will be split into two groups. The first group of participants will view a video of someone describing a detail-rich picture using only their natural arms to gesture. The second group of participants will view a video of someone describing the same picture but will use the additional arms as aids. Participants will draw or note what they think the picture looks like. From these results, we will evaluate the effectiveness of our additional arms for communicating spatial information.

Conclusion

Thus far, we have completed a pilot study and started construction of a prototype. From the pilot study, we have concluded that additional arms should be physically similar to the user's natural arms and extend from approximately the same area. Participants commented that additional arms are useful when describing an area from a static point of reference but were a hindrance when describing long paths where the point of reference changes. Our prototype is in the form of a virtual mirror where a user's body is augmented by two additional arms. Pilot study participants wanted to directly control the arms and so our current prototype allows users to move their additional arms using their hands. The current prototype remains limited and so further work is required before a user study can be conducted. Upon completion of the prototype, we plan to conduct a user study.

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