Office work involves many practical tasks that are difficult for people with a motion impairment. Even if the disability is slight or temporary, the fact that someone uses crutches, for instance, makes it impossible for them to carry books, stacks of paper or even a cup of coffee across the corridor. In fact, this need for assistance applies to anyone whose arms are busy.

This situation is the focus of a current project at IPLab, entitled “Fetch-and-carry-robot for functionally disabled people in working life”. Our idea was to develop a small, easy-to-use mobile unit that could assist a person in an ordinary office by transporting everyday objects within the local environment. We were particularly interested in how an intuitive and transparent user interaction with such a unit could be designed.

Little previous research in robotics has been directed at interaction design. There is a tradition of work in rehabilitation robotics, but the problems of temporarily or moderately disabled people are seldom addressed. For our part, it was important to deal with needs that could arise for anyone in a workplace, and to consider solutions that could involve a whole group and not just a single individual.

Together with our sponsors from the National Labour Market Board and the robotics research group at our department, we formulated the following initial requirements for the robot:

- The interface design should be transparent and easy to understand for both experienced and new users. This is necessary because an office is an open environment, and there is often more than one person involved in everyday transportation tasks.

Two basic ways of operating the robot were considered: (1) the robot independently goes to a specified location for collection or delivery of an object; (2) the robot follows the user around the office to assist with fetching and delivering objects. Because of technical constraints, the current prototype of the robot only operates in the first mode.

In the design of the robot, we have employed a user-centred methodology, collecting different types of information relevant to the situation of use, and iteratively feeding it into the development process. We have conducted interviews with a group of disabled office workers and used focus groups to yield an informal task analysis. A simulation study according to the Wizard-of-Oz paradigm preceded the development of the user interface, and gave important input into the design. At present, we have a working prototype that is being evaluated with users in a semi-realistic office environment.

Interfacing mobile artifacts

There are a number of challenges in designing human interaction with a mobile robot. The user needs to control the robot both in direct contact and when it is out of sight. While in the same room with the robot, the user may be moving around away from her desk, and cannot be expected to carry a computer or even a remote control unit. This led to the decision to use speech as one of the primary interface modalities.

On the other hand, there are situations when the user is stationary at her PC, and perhaps needs to use the robot while performing other computer tasks. Therefore a graphical user interface was seen as a natural complement. This may also be used to support additional parts of user interaction, such as...
customization, status information and error recovery. The two interfaces must use a common vocabulary as far as possible, and it should be easy for the user to switch between them.

**Wizard-of-Oz simulation**

During simulation trials, users were allowed to speak freely to the robot to instruct it. A ‘wizard’ had been trained to control the robot’s movements and generate dialogue responses. The results showed a great variability in the users’ communication style, which partly reflected the novelty of the situation. A frequent observation was that users appeared to be confused with regard to the robot’s state, particularly whether it had received their instruction and whether it was heading towards the desired destination. This was apparent from the users’ physical and spatial orientation to the robot: they often monitored its movements closely to see where it was going.

One main conclusion from this was that clear and explicit feedback to the user is needed on several levels in the human-robot interface. Such feedback may be partly verbal, but other means of displaying the robot’s state and direction were also looked for.

**CERO: a transportation agent as a "graceful driver"**

Many discussions in the design team centered around the central metaphor for interaction with the robot. This was also an important input into the physical design. Should the robot be given a personal, somewhat human-like appearance? Or should the image be one of the robot as a neutral transportation device? In the history of robotics, fantasies of an animated human robot persona have often been expressed, but these images did not seem applicable to our use situation. We wanted to convey to the user the sense of a friendly and reliable transportation agent, which gives a clear indication of where it is going and which is available for smooth interaction in a conversational mode.

**Wizard-of-Oz**

Designers of computer systems often like to be able to test the suitability of a proposed interface design before going to the expense of actually constructing it. In a Wizard-of-Oz study, a prospective user is fooled into thinking they are working with an actual computer system; in reality, a human ‘wizard’ is manipulating the interface in response to the user’s tests, using a protocol which describes how the system would respond if it were built.
The CERO-doll is placed on the robot’s front to give the user a sense of direction. The loudspeaker and the microphone are placed beneath and to the right of CERO. The antenna to the left provides wireless access to the local network of the office.

The solution that we have chosen is based on a new metaphor, consisting of a transportation platform and a “driver”. The driver represents the robot’s personality and intelligence and provides a focus for interacting with it. To embody this idea we created a physical character, CERO (Cooperative Embodied Robot Operator), with a simple body language of arm and head movements. In this way, feedback can be given on the user’s requests, complementing the speech output from the system. The CERO character can be used to display the robot’s state, but it also gives a clear direction for the robot and helps the user orient to it during interaction.

**Natural interaction with the CERO agent**

A flexible spoken language dialogue has been designed for the fetch-and-deliver scenario. The dialogue is designed to ensure mutual understanding, while giving the user several options for how to approach and instruct the robot.

In the following example, the robot acknowledges the user’s request by reformulating it as a question. This is affirmed by the user; which has the effect that the robot starts on the mission. The gestures of the CERO character provide simultaneous feedback on the robot’s status.

**User:** robot, get coffee in the kitchen!
**CERO:** (displays gesture of attention)
**Robot:** get coffee in the kitchen?
**User:** yes, please
**Robot:** going to get getting coffee in the kitchen!
(robot starts moving)

We are exploring ways of providing non-intrusive communicative feedback at different points in a spoken dialogue. This includes both conversational feedback, providing reactions to the user’s commands, and co-expressive conventional gestures (e.g. emblems: nod, shake head, call for the user’s attention…).

In the graphical interface, the environment and the robot itself are depicted in such a way that the user can follow the robot’s movements. The CERO character is visible in a corner, and is animated to give feedback while a transportation mission is activated. The user instructs the robot by using drop-down menus with words reminiscent of the spoken command language. It is also possible to interrupt a mission and obtain system information.
User reactions

We have begun to evaluate the system with users in realistic tasks. The results have shown that the model for human robot interaction using speech and an artificial character is a viable alternative to the portrayal of the robot as neutral transport appliance. The general design of the robot, with the CERO-doll and a multi-modal way of operation, has been well received by the users. The menu-based graphical user interface is familiar to the user’s (interface) and thus supports the exploration of the robot’s functionality, while the speech interface requires some training but enables interaction without the use of a graphical display.

Conclusions and future work

The process of designing a human-robot interface for people with transportation needs is a new and challenging area for HCI and interaction design. Our work has been guided by goals of simplicity and naturalness for the user, but also by constraints of existing technology in terms of robot platforms, available sensors and processing power.

In future work, we hope to extend the robot’s communicative capacity and to explore further the social and collaborative aspects of sharing an intelligent transportation agent in a workplace. We see the CERO agent as the first component of an intelligent physical environment with support for people’s everyday tasks in a workplace.

References


Acknowledgements

This work has benefited greatly from collaboration with industrial designer Erik Espmark, who created an interesting appearance for the CERO character and provided us with sound principles leading to the robot’s exterior design.

We thank our colleagues at the CAS research centre, in particular professor Henrik Christensen, for valuable assistance and for permission to use their sonar navigation system in the CERO robot.

The research presented here has been supported by the Swedish Labour Market Board (AMS), and the Swedish Foundation for Strategic Research (SSF) through the Graduate School for Human-Machine Interaction.