Wheelchair Guidance using HCI Strategies: A Short Survey

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Abstract— **This paper presents different Human Computer Interfaces (HCI) strategies for the wheelchair guidance in the last decade. A basic goal of HCI is to improve the interaction between users and computers (intelligent wheelchair) by making robotics wheelchair more handy and receptive to the user's needs. Some strategy is more invasive than the others. To be decided by a single certain strategy is not easy, but the strategy to follow is going to depend on the physical possibilities of the users; even, to times, it is possible to be decided on a combination of some of them.**

I. Introduction

In the last years, there has been a significant increase in the development of assistive technology for people with disabilities, improving the traditional systems. Also, the growing use of the computer, both in work and leisure, has led to the development of PC-associated handling applications, mainly using graphic interfaces. This way, the traditional strategies of control or communication between humans and machines (joystick, mouse, or keyboard), that require a certain control motor on the part of the user, they are supplemented with others that allow their use for people with severe disabilities.

The strategy to follow is going to depend of the degree of handicapped person.

Among these new strategies it is necessary to mention voice recognition [1] or visual information [3]. For example, using voice recognition it is possible to control some instruments or applications by means of basic voice commands or write a text in "speech and spell" applications. Other options are based on electro-oculography mouse [2] for displacing a pointer on a screen. The development of brain machine interface (BMI) [12] or brain computer interface (BCI) [13] has flourished in past years [4]. The infrared videooculography (IORG) for detecting gesture or face tracking [4] and the eye tracking by videooculography (VOG) [5] are other strategies for wheelchair guidance.

This paper has been divided into sections: of more invasive to less invasive, depended of the strategy of the system. Section II presents the first working prototype of a brain controlled wheelchair able to navigate [4]. Section III proposes different wheelchair guidance strategies by means of electrooculography [2]. Section IV describes a voice control system was implemented within NavChair System [1]. In the Section V, a novel head gesture based interface presents for intelligent wheelchairs [5]. The Section VI presents a system based on the Active appearance Model (AAM) by Stegman, where is very important the extraction and analysis of the facial features: the head-pose, the gaze [6], movements of eye-brows and lisps. Finally, Section VII draws the main conclusions.

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II. Strategies by Brain-Controlled

This section presents the first working prototype of a brain controlled wheelchair able to navigate inside a typical office or hospital environment. This Brain Controlled Wheelchair (BCW) is based on a slow but safe P300 interface. EEG is the most common recording method used in Brain Computer Interface (BCI), providing a continuous time measurement with a simple portable system. In EEG, a set of electrodes are applied on the scalp and wired to an amplifying-filtering-digitalizing device, which transfers the signal to a computer for further analysis specific to the paradigm and application. The electronic equipment needed is currently smaller than a laptop and less than one kilogram (see fig 2).

Fig. 2. Photographs of the acquisition devices and brain controlled wheelchair during experiments in a typical office environment. Note the compact portable system including signal amplifier, filter and acquisition device.

The first working prototype of a BCW able to move in flats or office like environment or in a hospital is presented in [3]. It relies on a path following strategy that provides simple control of necessary movements while avoiding costly and potentially unsafe complex sensor processing, and on a slow but safe BCI used to generate simple commands.

Our current BCI may appear to suffer from the slow response time, however one must replace this in the context of potential users. The system is intended for people who are unable to move and normally stuck in bed; their notion of time is different from ours and being able to move independently within their environment represents a big improvement for their quality of life, whether it takes time or not. In this context, safety and reliability are much more important than speed.

One concern with the slow response time of our BCI, however, is that it prevents fast reaction to any unexpected event such as an obstacle suddenly appearing on the path.. The motion control simplification brought by the guiding paths enables the use of simple sensors and stop reflexes, which are reliable and safe. Faster BCI that are expected to appear in the near future will also profit from the significant simplification brought by path guidance and the path editor described in this paper. This will significantly contribute to safety and simplify control without the need of complex sensory processing.

The system also provides tools for users to optimize the guiding paths to the their satisfaction and to adapt to changes in the environment. Finally, because the movements along the same guiding paths are repeated other time, the wheelchair's motion is predictable, so that the user can relax during the movement.

III. STRATEGIES BY EYE-TRACKING WITH EOG

One form of communication that is of particular interest here is the detection and following of the eyegaze or eye control systems. Many people with severe disabilities usually retain intact their control capacity over the oculomotor system, so eye movements could be used to develop new human machine communication systems.

This section describes an eye-control method based on electrooculography (EOG) [2] to develop a system for assisted mobility. EOG is a method for sensing eye movement and is based on recording the standing corneal-retinal potential arising from hyperpolarizations and depolarizations existing between the cornea and the retina; this is commonly known as an electrooculogram. The EOG value varies from 50 to 3500 µV with a frequency range of about dc-100 Hz. Its behavior is practically linear for gaze angles of $\pm 30^{\circ}$. The electrooculogram is captured by five electrodes placed around the eyes.

The wheelchair can be controlled using EOG by various guidance strategies: direct access guidance, guidance by automatic or semiautomatic scanning techniques and guidance by eye commands. A period of training is necessary to learn to guide a wheelchair by EOG techniques.

Nevertheless, the results obtained in guidance using a technique or another are similar, although the electro-oculography is more uncomfortable in principle to the user since it requires electrodes. However, in function of the type and degree of handicap it is more interesting to use one or other, being observed that if a person presents a good control on its head movements it is more comfortable videooculography, but if the control of the head movements is reduced, the electrooculography can present better results. It should be kept in mind that each person has different qualities and to establish a comparative one among different people cannot be appropriate.

The goal of this control system is to guide an autonomous robotic wheelchair using electrooculographic signal generated by eye movements within the socket. Fig. 1 shows the user guidance interface.

Fig. 1. Example of semiautomatic scan guidance.

IV. STRATEGIES BY VOICE

The systems of control of the voice described in this sction were put in execution for the University of Michigan: the NavChair Assistive Wheelchair Navigation System [1], and for K. Komiya and K. Morita [7].

Voice control (VC) is an attractive option for several reasons. The VC systems can be used by any individual capable of consistent and distinguishable vocalizations; therefore, VC is potentially appropriate for a large number of wheelchair users. VC would also reduce the physical requirements of operating a wheelchair.

Unfortunately, voice control has proven difficult to implement within a standard power wheelchair. One difficulty is the very real possibility that a voice input system may fail to recognize a user's voice. Another problem is the limited rate by which information can be transmitted by voice. An experienced voice recognition user can enter between 30 and 50 words per minute. In practice, this makes voice input useful for general directional commands used in operating a wheelchair in open spaces but inadequate for rapid correctional maneuvers in crowded environments.

The NavChair is being developed to provide mobility to those individuals who would otherwise find it difficult or impossible to operate a power wheelchair. The NavChair was chosen for this project because the navigation assistance it provides to the user makes it possible to ensure the user's safety while limiting the amount of interaction required between the user and the wheelchair. The NavChair's navigation assistance allows the wheelchair operator to supply gross directional commands while the NavChair itself makes the numerous small corrective maneuvers actually needed to reach the target. Most important, the NavChair's obstacle-avoidance capability means that misinterpreted or ignored commands will not cause a collision.

Navigation assistance represents a viable design alternative that allows the voice interface to be simplified and helps to maintain the safety of the operator and the wheelchair. More important, we believe the results we observed apply equally well to other discrete wheelchair control methods. A set of switches is functionally equivalent to the set of voice commands used by subjects during this experiment, and it is likely that users of these wheelchair control methods would receive similar benefits from navigation assistance.

The wheelchair operator uses voice commands to indicate the desired path of travel, and this information is combined with information about the wheelchair's immediate environment (from the sonar sensors) to identify a safe path of travel. The control signals that correspond to this path of travel are sent to the wheelchair motors, dictating the direction and velocity of the wheelchair.

A wheelchair is an important vehicle for physically handicapped persons. However, for the injuries who suffer from spasms and paralysis of extremities, the joystick is a useless device as a manipulating tool. They cannot operate the joystick smoothly at all. So, a voice command system may be a good information transmission means of high efficiency and low load for such users. A voice command system has been applied in other fields. Interface Agent for Process Plant is one example. But, most research is of no practical use because of problems such as control due to time delay for a voice sensing or misrecognition.

In [7], K. Komiya and K. Morita discuss the experimental results of successfully running by voice using micro-robot KHEPERA. Two kinds of running mode are compared from the points of running time and frequency of commands and so on. The keyboard input and voice input are compared. Lastly, before making an experiment by a powered-wheelchair, experimental tests by the simulator were done. This experiment aimed to find any problems for running outside the room. Also, it was checked whether the basic commands used would be enough to run. Some experiments were tested by actually running a powered-wheelchair.

V. STRATEGIES BY FACE TRACKING

In this case, the system computes the face direction from images of the user-observing camera [8],[9], [10], [11]. We can pass our intentions to the system by turning our face. The problem, however, is that we move our head in various other occasions than in controlling the wheelchair's direction. The system needs to discern wheelchair-control behaviors from others. This is the intention understanding problem in the current system. Our basic assumption is that we move our head slowly and steadily when we are told that the wheelchair moves in our face direction. Thus the system ignores quick head movements, only responding to slow steady movements. Figure 3 shows the general system architecture. Through a CCD color micro camera, placed in front of the user, the face images are acquired. These images are digitized by a frame-grabber and loaded in a PC Pentium memory.

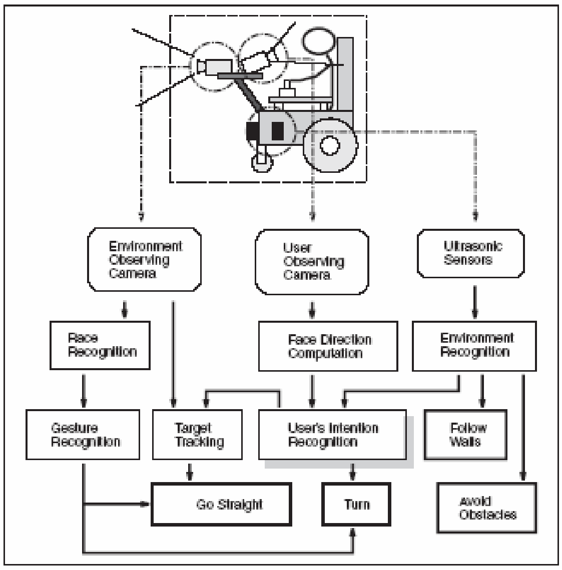

Fig. 3. System Configuration.

There are, however, cases that we looking a certain direction steadily without any intention of controlling the wheelchair. For example, when we notice a poster on a corridor wall, we may look at it by turning our face in its direction while moving straight. In general, if there are any objects close to us, we may tend to look at them for safety and other reasons. In these cases, we usually do not want to turn in those directions. However, we cannot exclude the possibility that we really want to turn toward those objects.

VI. STRATEGIES BY EYE- TRACKING WITH VOG

Since Ekman and Friesen developed the Facial Action Coding System (FACS) several groups are busy with the automatic classification of so called Action Units (AUs), which represent the minimal muscular activity that produces momentary changes in facial appearance. For a good classification an accurate feature extraction is very important (figure 4). The eyes (specially the brows), the mouth (specially the lips) and temporally appearing features like shadows on the face (like furrows) are well suited attributes for the subsequential classification.

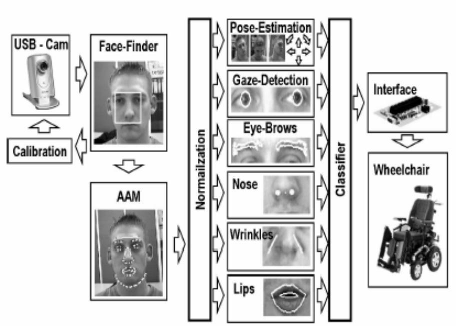

Fig. 4. System-overview of feature extraction: After the matching of the person-adapted AAM-model the areas for interested becomes more detailed investigated. Finally a classifier analyze the won features and send a command to the wheelchair.

For estimation of gaze direction, the eye-region is extracted with support of the AAM. Typically the pupils are dark objects and part of the search-mask. On a gradient-map a circle-hough-transformation is applied, where we weigh the result with the gradient's phase.

The gaze detection is performed by calculating the correlation of simple templates centred on the pupil. The templates are created from synthetic views of sclera and iris which 'look' into different directions. To analyze the eye-brows we assume that they are located above the eyes and not occluded by hair.

VII. Conclusions

As the present review demonstrates, to improve quality of life for the elderly and disabled people, intelligent wheelchairs have been rapidly deployed over the last years. Various research and developments are implemented strategies for guidance of intelligent wheelchairs, but the strategy to follow is going to depend on the physical possibilities of the users, and if some strategy is more or less invasive.

The strategies by BRAIN-CONTROLLED, they have been proven in healthy people and there are significant differences in responses between healthy and disabled individuals.

The strategies by EOG allows the handicapped, especially those with only eye-motor coordination, to control a wheelchair. The system is considered like invasive.

The strategies by VOICE, based on users' subjective ratings alone, navigation assistance is clearly preferred when using voice control. When there was no navigation assistance, collisions were typically caused by the voice recognition system's inability to correctly recognize a command or the subjects' inability to make rapid compensatory control inputs when navigating in confined areas.

The strategies by FACE TRACKING, observes the user and the environment. It can understand the user's intentions from his/her behaviors and the environmental information; for people who find it difficult to move their faces, it can be modified to use the movements of the mouth, eyes, or any other body parts that they can move. By another part the strategies by EYE-TRACKING are used for heavily handicapped persons, who are not able to use their hands precisely, it would be much more comfortable, to control a wheelchair by facial expressions and the extraction and analysis of the facial features: the gaze, movements of eye-brows and lips.

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