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Multimodal Wheelchair Control for the Paralyzed People

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Introduction

Most serious accidents and injuries often end with various motoric disabilities usually resulting in a limited control of the muscles of various body parts and in some worst case scenarios even the whole body. In our research we concentrate on the development of a natural and effective associative HCI interface for a mobility device for the paralyzed people, trying to combine the traditional input with speech and video recognition technologies into one multimodal control "package". The associated governmental support programs of today are targeted at providing the technological means enabling the handicapped persons to have as independent life as possible.

Standard mobility devices such as typical manual or electrical wheelchairs naturally do not fit our targeted audience due to limited capabilities of the paralyzed people. Multimodal approach might allow overcoming this problem. Simply put, depending on the level of paralysis, the person might be able to move a finger, he might also be able to speak, or in worst case he might still be able to move his eyes. Naturally the creation of the multimodal control interface combining various input and output modalities looks like a reasonable choice. Such interfaces especially when combined with mobile technologies can have tremendous implications on usability, accessibility and consequently for people with an even wider variety of impairments. The weaknesses of one modality are offset by the strengths of another. Separate control methods (even some combinations) were already analyzed by other scientists.

The novelty of this project is the integration of the traditional input with speech and video recognition techniques and in the future even more (i.e. brain activity scanning) into one associative control interface targeted at fully and partly paralyzed people groups. We believe that by combining the main and most natural (by a human – human interaction point of view) input and output modalities (i.e. touch - if a person can move a finger, speech recognition – if he can speak, gaze recognition and eye tracking – if he can still move his eyes, etc.) with environment tracking techniques (obstacle avoidance, maybe even some path finding) or even communications with other devices (i.e. smart home equipment) we could create a viable product necessary to help people with the very special needs. Another advantage of our proposed approach is the scalability factor – we design the interface to be modular, thus allowing an easy scalability and porting to other innovative and intuitive control devices.

State of the art

The area of multimodal input and output research is not new. Many studies were and still are targeted at helping the socially dependent people. A whole lot of different techniques ranging from the voice recognition to brain scanning are being evaluated trying to provide some technological aids and solution [1].

As speech is the most natural form of human – human communications many solutions are being developed based on speech recognition ranging from integral microchips [2] to the appliance of fuzzy logic in case of noisy or unclear speech [3]. Sadly despite all efforts speech recognition is still not up to human speech interpretation standards and sometimes does not work or work poorly (for example in noisy environments). Thus the combination with other control modalities such as video recognition techniques is a very important factor in a multimodal system design. For example, lip contour extraction is another useful technique for obtaining a mouth shape in an image, and has already become one of the most important techniques for human-machine interface applications in multimodal control schemes such as lip reading and speech recognition and is already implemented in some wheelchair prototypes [4].

Video recognition techniques are another trend in control interfaces. For example eye based control can be developed utilizing an Artificial Neural Networks [5] where the neuron network of radial base functions can be used for the interpolation of screen points. Some researchers prefer the electrooculography based human-wheelchair interfaces [6], where a pair of electrodes which measures the eye-gaze direction of users is used as wheelchair manipulation commands.

A multi-modal approach is also common, for example a system to control the movement of an electric wheelchair using a small vocabulary word recognition system and a set of sensors to detect and avoid obstacles [7] or a combination of eye-tracking with simple obstacle recognition by detecting special markers in compound spaces [8]. Path finding, autonomous driving are the very important parts of robotic guidance being integrated into wheelchairs, ranging from the simple solutions such as sonars or an infrared sensors providing a partial guidance similarly to car parking systems [9, 10]. More complex solutions offer full autonomous guidance [11] based on physical, local and global levels such as free-space detection, wall detection, free-space search, direction following, wall following, motion control, obstacle avoidance, etc. However some still prefer to emphasize the human-centered manipulations instead of fully autonomous operations [12].

Various manipulators to compensate the arm disabilities are also being used in wheelchair designs, ranging from basic robotic arms capable of autonomously tracking a steady target and grasping the target via visual servo controller [13] to an advanced carbon fiber modular devices, incorporating DC servo drive with actuator hardware at each individual joint, allowing reconfigurable link lengths with seven degrees of freedom meeting the needs of mobility-impaired persons with a limitations of only upper extremities [14].

AI is also an important factor in autonomous wheelchair designs. Novel approaches, for example [15] are based on user plan recognition, allowing estimating not only the user's low-level intent (i.e. go to a point), but also a high-level intent (i.e. open a door).

Multimodal wheelchair control algorithm for the paralyzed

Most researches are developing the interfaces for the widest audience of semi disabled people (those capable of speaking, moving a bit, etc.) while we target the most unfortunate ones (fully and partially paralyzed), integrating various types of inputs and outputs into one associative, modular control package, where all the modalities supplement on another or are enabled / disabled based on a person's needs and abilities. At the current stage we are concentrating on the following three main control modalities:

1) A speech recognition system capable of recognizing a predefined list of Lithuanian voice commands;

2) An eye tracking system capable of tracking the movement of eye pupil – i.e. gaze tracking;

3) A special "cursor" centric touch recognition system capable of detecting the direction of finger or tongue movement on a sensor surface.

A simple, but very effective control algorithm was developed to control the wheelchair (Fig. 1). At the beginning of a dialog a user inputs some control command (either by swiping a finger through a touch plate, by uttering a voice command or by moving an eye). Depending on the configuration and his abilities a user might be able to use more than one input modality. In this case the overriding (primary) input is chosen (based on the preset, or even by the user (if capable) himself. Next the signal is sent to an appropriate processing block.

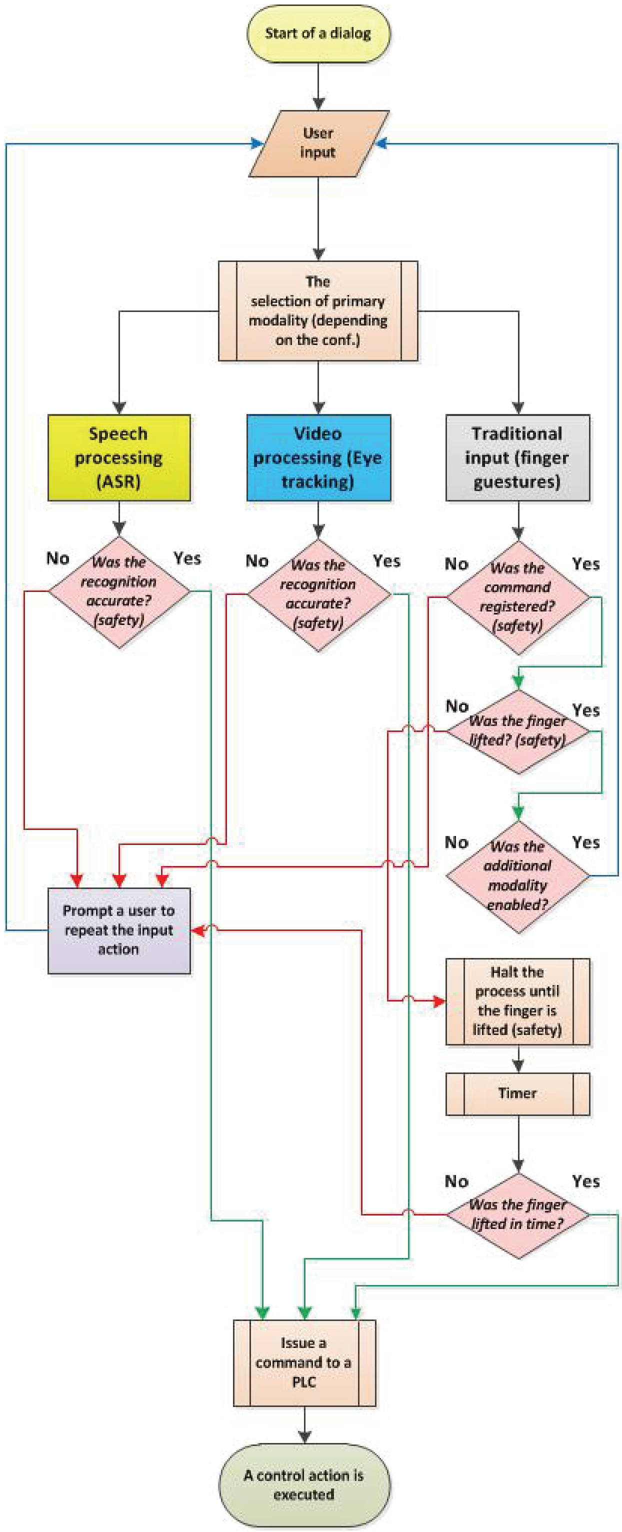

Fig. 1. The proposed algorithm of multimodal control

In case of the traditional input (figure gestures) a security solution was introduced as a safety feature. A person must lift his finger (or tongue) after each swipe. If he does not lift a finger after a preset time, the command is rejected and he is asked to repeat it. An easy option to enable or disable additional modalities is also offered for the user (for example if his tongue or finger is tired of swiping). A user may enable speech recognition and gaze tracking simply by touching left or upwards sides of the input pad. For safety reasons the additional modalities are disabled after each successful recognition of an input (must be enabled again by touching an appropriate zone).

In case of speech recognition and eye tracking, the confidence measure of uttered voice command or gaze recognition is compared to a model and if it is high enough the system issues a command to a wheel chair motor (for example TURN LEFT if a user said so). If the recognition accuracy is low – the user is asked to repeat the input.

Implementation

We have chosen a modular architecture for the technical implementation of the mobility device. The wheelchair itself is a standard issue wheelchair with added gears, dual motors (one for each wheel), automation controller (relay and USB interface) block and a set of I/O modules (Fig. 2). At a current stage all processing operations are done on a netbook pc.

Touch input was chosen for a traditional input and in principle is compatible with most touch input devices, such as smartphones, computer touchpads, touchscreens, etc., capable of detecting the movement and the direction of a pointer (a finger or a tongue) thus providing the direction vector used for wheelchair control. This modality was designed under eyes-free interface design guidelines, meaning that the graphical feedback is not necessary and allowing a control, just by swiping a surface space (the virtual "cursor" always returns back to the center). For safety reasons the system does not react to a user input if a finger is kept pressed down continuously. Software allows enabling the other two modalities if a user whishes so or is able to use them.

The voice command recognizer capable of recognizing simple phrases, for example direction commands, such as (the words in brackets are optional): "(važiuok) pirmyn, (važiuok) atgal, (suk) kairėn, (suk) dešinėn, etc." was implemented to control a wheelchair. A proprietary Lithuanian speech recognition algorithm [16, 17] was chosen, capable of being adapted to any foreign language based recognizer, thus allowing easer porting to integrated devices with built-in recognition systems (usually only English).

The video recognition - eye tracking was realized under the ANN based software developed by other Lithuanian scientists [5], thus enabling the device to turn left or right, move forwards and backwards based on the movement of the eye pupil.

A software can be configured to allow all three control modalities to be used together, thus complementing each other, although eye tracking for safety and concentration issues should be enabled only if the other controls are unusable and can also be configured independently by a supervisor or enabled by a person himself (using a special zones of the touch surface) if he is capable of using more than one modality.

A control algorithm is still in the prototype stage as experimental testing, final end-user evaluation and fine-tuning of control and response of the device itself, the use of reliable navigation and mapping tools remain to be investigated in near future to implement the movement assistance and autonomy in confined spaces.

Fig. 2. A multimodal wheelchair

Conclusions and future work

The tradition input (touch) was combined with voice recognition capabilities and eye-tracking into one associative interface aimed at a control of the mobility device for fully and partly paralyzed people, creating a scalable and very intuitive HCI interface.

The solution is not universal – every disabled person is different: some might expect a "real-life companion" from a speech interface; some might be unable to stick to a predefined control scheme; some might have a psychological fear of technology (unable to use a system if no human is nearby).

Near future experimental analysis and fine-tuning remains to be done, trying to determine and overcome different issues on how the device performs in various environmental conditions, how the recognition accuracy affects overall usability, how good and natural is the designed interface for the final end user (a disabled person). Also the possibilities of integrating the autonomous navigation features, such as environment sensing, path-finding and remote audio-visual tracking and control for the care personnel need to be determined.

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Most serious accidents and injuries often end with various motoric disabilities usually resulting in a limited control of the muscles of various body parts and in some worst case scenario even the whole body. The associated governmental support programs of today are targeted at providing the technological means enabling the handicapped persons to have as independent life as possible. In the presented research authors concentrate on the development of a mobility device for the paralyzed people, trying to develop an effective multimodal HCI algorithm by combining the traditional input with speech and video recognition technologies into one associative "package". Paper reviews some of the associated research on the topic, a proposed algorithm for the multimodal wheelchair control and a scheme of implementation. Ill. 2, bibl. 17 (in English; abstracts in English and Lithuanian).

R. Maskeliūnas, R. Simutis. Multimodalinis paralyžiuotųjų vežimėlio valdymas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 5(111). – P. 81–84.

Nemaža didelių avarijų ir nelaimingų atsitikimų baigiasi žmogaus motorikos sutrikimais. Paprastai sutrikdoma rankos, kojos, veido ar, blogiausiu atveju, net ir viso kūno raumenų veikla. Praktiškai labai sunku yra suvienodinti vieno ar kito sutrikimo techninius sprendimus, nes reikia nagrinėti konkrečius kiekvieno žmogaus simptomus ir taikyti skirtingas gydymo ar pagalbos metodikas. Dėl šios priežasties šio tyrimo autoriai apsiriboja visiško ir dalinio kūno paralyžiaus atvejais, kad sukurtų efektyvią žmogaus ir mašinos sąsają, valdymui panaudodami tris pagrindines įvesties ir išvesties modalijas (lietimą, šneką ir vaizdą) ir integruodami jas į vieną asociatyvųjį valdymo algoritmą. Straipsnyje pristatomos pasaulyje taikomos technologijos, autorių siūlomas sprendimas ir jo techninio įgyvendinimo schema. Il. 2, bibl. 17 (anglų kalba; santraukos anglų ir lietuvių k.).