Human in loop Integration of a Wheelchair Mounted Robotic Arm through Brain Machine Interface

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We developed a human in loop integration system for our wheelchair mounted robotic arm, with a brain machine interface utilized as the interacting device in an attempt to enable the aid for users with limited motion ability in activity of daily livings. In order to enable a reliable use of the brain machine interface, operation status of the manipulator are defined, an intelligent supportive module is also exploited, which utilizes neuronal signals identification result and also face expression to generate an binarized command code input, that are then used to drive the transition between operation status of the manipulator. The corresponding motion control action will be executed due to the transition of operation status.

Key Words: ADL Support, Intention Transmission Support, Brain Machine Interface

1. Introduction

Industry robots played up to now the most important role in real-world applications. However, with the theoretical progress as well as technical advances in the research field of robotics, and also the exponentially increase of computer power, it make us to believe that it is the time to develop the robots that work in the vicinity of and together with humans, for example, the assistive and rehabilitation robots that will be under great requirement in the more and more aging society to support disabled as well as elderly people during their daily life activities[1]-[3], has attracted the attention of a great number of researchers in both industry and academic society. Such robotic systems are always comparatively challenging and greatly benefit from the improvements in sensor systems and control techniques.

Wheelchair mounted robotic arm (WMRA) is one kind of assistive and rehabilitation robots that works in the close vicinity of human beings. It is developed as an assistive device, in an attempt to help elderly and disabled people to recover some manipulation capabilities in activities of daily livings (ADLs). The idea of WMRA comes from the healthcare condition survey which showed that a lot of disabled people as well as a growing number of elderly people owing to the more and more aging society, have difficulty performing functional activities and requires an assistive device to enhance their manipulation ability. WMRA is a robotic solution that combines the idea of a mobile based manipulator and a powered wheelchair as the platform to mount the manipulator, several WMRA systems have been developed for use in both academic and industry society [4]-[6] for example, the "FRIEND II" and "FRIEND III" projects that are under progress in University of Bremen, the commercial available arms: the Manus manufactured by Exact Dynamics, and the Raptor manufactured by Applied Resources. The idea of these WMRAs could provide the users with combined mobility and manipulation control, for the assistance in ADLs.

In an attempt to design a wheelchair mounted robotic arm system that can help the users to interact with the unstructured environment effectively, the interfacing device between humans and robot have revealed its great importance. When we design the human machine interface,

the different level of cognitive ability of the users has to be taken into consideration, because of that the dexterity of different physical disabled people may vary from finger motion to wrist motion to gross arm motion, due to the user's level of disability, functional capability, and preference, thus result in the difference in user s' cognitive ability. A number of human-robot interfaces including "Joystick", "Touch screen", "Speech interface" and "Head tracker" has been developed to adapt the interactive tasks where users has different level of physical disability. We have studied the possibility of utilizing a "Brain machine Interface" for the manipulation of our developed wheelchair mounted robotic arm system. The human in loop integration framework are also proposed that integrates the humans and robots as a whole for task execution in activity of daily livings.

Fig. 1 Wheelchair mounted robotic arm system

In this paper, our research is mainly focused on the human in loop integration of our developed wheelchair mounted robotic arm through brain machine interface. A light weight

robotic arm which equipped with mechanical gravity compensation was implemented and mounted on a powered wheelchair to formulate the hardware platform of our robotic system, see Fig. 1. External sensors such as torque sensor and stereo camera are also incorporated, together with a brain machine interface to realize the overall human in loop integration robotic system.

2. Hardware configuration

The hardware platform of our wheelchair mounted robotic system mainly consists of a powered wheelchair and a light weight manipulator mounted on the wheelchair. See Fig. 2

Fig. 2 Hardware configuration

A commercial powered wheelchair product is adopted as the mobile platform of our robotic system, which can be controlled by a wheelchair controller for the speed, direction, and lift motion control. The mechanical gravity canceller is incorporated in the design of manipulator to balance the link gravity in arbitrary postures by generating the corresponding gravity compensation torque through the force of a linear torsion spring, thus enable the realization of a light weight arm with 5kg self weight and 2 kg payload. Four degree of freedom is designed to achieve the desired manipulation flexibility for the application of task execution in activity of daily livings. The four degree of freedoms are separately controlled through four motor controllers with position, velocity and current control. All the control functionality and external sensors are integrated through a work PC, as can be seen in Fig. 2.

A "Brain machine Interface" is adopted as the interacting device between the humans and our developed wheelchair mounted robotic arm. Brain machine interface is a direct communication pathway between the brain and an external device, aimed at assisting, augmenting or repairing human cognitive or sensory-motor functions. For the user who is unable to control any mechanical interactive devices due to the limited arm motion or finger motion ability, brain machine interface may be a good alternative. We adopted a commercial brain machine interface as the final alternative for the users with extremely physical disability. The brain machine interface can be utilized for the activation or stop of a specified operation, and also to shift between options

provided by a software interface.

3. Interfacing through brain machine interface

With respect to the application of wheelchair mounted robotic arm system, Brain machine interface is considered as an ideal interacting device especially for the users who can not interact through any mechanical interactive devices due to the limited physical motion ability. However, because of the lack of knowledge in neuroscience about the understanding of the relationship between motor motion and neuronal signals, it is always difficult to utilize mathematical models to extract several motor parameters (i.e., hand position, velocity, gripping force, and the EMGs of multiple arm muscles) from the electrical activity of neuronal ensembles that is represented and detected in the form of neuronal signals, thus make it is difficult or even impossible to use the detected neuronal signals for the generation of corresponding physical motions. The complexity and instability of neuronal signals also reduced the accuracy and reliability of the brain machine interface based applications.

In order to utilize the brain machine interface more reliably to control the manipulator motion in our wheelchair mounted robotic arm applications, we have developed a intelligent supportive module which can utilize the result of neuronal signals identification simply and reliably for the control of manipulator motions.

In the design of our intelligent supportive module, operation status are defined for the manipulator, such as "Waiting command", "Standby", "X direction motion", "Y direction motion", and "Z direction motion". Each operation motions provide its specified graphic prompts to the users for command inputs, thus the users generate corresponding command code through the brain machine interface. The command code is a combination of binarized digit, each digit can be set through the power of neuronal signals, whereas the shift between each bits are achieved through the facial expression. The binarized command codes are then used to drive the transition of operation status, thus result in corresponding control actions. See Fig. 3.

Fig. 3 Intelligent supportive module,

We use an example to illustrate the processing method of our intelligent supportive module: during the operation status of "Waiting for command", a specified graphic prompts is shown to the users for the input of a 3 digit command code,

with the 3 digit represent the activation of "X direction motion", "Y direction motion", and "Z direction motion" respectively, thus the command code input is completed in the way that the users utilize the facial expression to shift between these 3 digits and the power of neuronal signals to set each digit. If 010 is generated which means the activation of "Y direction motion", thus the operation will be transited to the "Y direction motion" and result in the corresponding motion control.

4. Conclusion and future works

In an attempt to construct a human in loop integration system of our wheelchair mounted robotic arm incorporating the user with limited physical motion ability, a brain machine interface was utilized as the interacting device. An intelligent supportive module was developed, which can utilize the power of neuronal signals and face expressions to drive the transition of operation status, thus result in corresponding motion control.

In our future works, sensor based automatic task execution will be incorporated, thus can be driven by the brain machine interface to complete the execution of high level tasks.

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