Functional Electrical Stimulation with the Optimal Strategy for Restoring Quadriplegics’ Hand Functions

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Abstract

Nowadays there are many assistive devices developed for restoring a quadriplegics’ lost functions by functional electrical stimulation. If patients can use their residual capabilities to control these devices, it will be very helpful for them. However, the input sources or the command controller might be complicated or inconvenient for them to use. If the optimal strategy of controlling has been built, they will benefit from it. In this study, we try to design the optimal strategy of the patient-driven command controller for restoring their lost hand functions by functional electrical stimulation. The proposed optimal control strategy can also be modified and applied for different rehabilitation applications.

Keywords: Command Controller, Hand Function, Optimal Strategy, Functional Electrical Stimulation

Introduction

Quadriplegics, with hand paralysis who were due to spinal cord injuries (SCI) or other neurological impairments, lose their ability to grasp objects for activities of daily life (ADL), such as eating, drinking, writing, brushing teeth, etc. They are unable to perform these activities independently, and it may also increase the loading to their families both economically and mentally. Apparently, it is very desirable and urgent to develop a practical system that can be used by quadriplegics to restore their gasping functions.

Nowadays there are many assistive devices developed for restoring their lost functions. Functional electrical stimulation (FES) and neural prostheses are very popular in the clinic usage. Although these systems are highly developed, the input sources or command controller are very complicated and inconvenient for the patients. If there is an optimal strategy for the input source or command controller, it will be helpful for them to restore their lost functions. Besides, they can use their residual capabilities to control these assistive devices. It is also good from the aspects of rehabilitation and psychology. In this paper, we will have discussions on the optimal strategy of the patient-driven command controller in rehabilitation applications, and we will take the restoration of hand functions by functional electrical stimulation as an example.

Materials and Methods

In order to find the optimal strategy of different input sources before the paralyzed hand muscle can be actually controlled by a command controller, there are several important issues need to be dealt with. Firstly, it is necessary to systemically profile the muscles that perform hand functions when applying the electrical stimulation for individuals. Secondly, we need to synthesize the stimulation template to get the so-called multi-state setting of the hand motion. To analyze the hand motions, there are multi-state settings such as the neural position of the hand, hand opening, grasping, etc. Thirdly, the optimal stimulation template is needed in order to find the proper electrical stimulation parameters during different hand motions. After finding the profiles of targeted muscles and the proper electrical stimulation parameters, motions produced by FES go more smoothly.

On the other hand, the aim of this study is also to develop a patient-driven command controller for quadriplegics. With their residual capabilities, they can control the assistive device bitterly using the optimal strategy of FES.
To begin with this study, we will have normal people to build the stimulating templates and muscle profiles. When this preliminary study has been done well, the quadriplegics, such as the C5/C6 patients, will be involved in the study.

Results

Because we wanted to know the states of hand motions, the cylindrical grasping and lateral pinching were selected in this study. As depicted in Figure 1, the motion-oriented modules had been design to profile the related muscles. The muscles included flexor digitorum superficialis, flexor digitorum profundus, thenar muscle, extensor digitorum, extensor pollicis longus, and extensor pollicis brevis. Besides, the electrical stimulator used here was developed in our own laboratory [1], and the man-machine interface was designed using LabVIEW program [2]. Three able-bodied subjects participated in this study. The preliminary results of the motion-oriented modules were showed in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Grasping</th>
<th>Releasing</th>
<th>Frequency</th>
<th>Pulsewidth</th>
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<tr>
<td>Subject 1</td>
<td>27 mA</td>
<td>25 mA</td>
<td>20 Hz</td>
<td>200 us</td>
</tr>
<tr>
<td>Subject 2</td>
<td>23 mA</td>
<td>22 mA</td>
<td>20 Hz</td>
<td>200 us</td>
</tr>
<tr>
<td>Subject 3</td>
<td>27 mA</td>
<td>24 mA</td>
<td>20 Hz</td>
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Figure 1. (a) Motion-oriented module of cylindrical grasping, (b) Motion-oriented module of lateral pinching

Discussions and Conclusion

The optimal strategy is very important for the patient-driven command controller. Patients can use their residual capabilities to control the assistive devices elegantly if the optimal control strategy is applied. In this study, we hope that with the designed command controller, the patients can voluntarily control the grasping postures and grasping forces themselves. It is expected that the command controller should be able to (1) detect and quantify the user’s residual capabilities and (2) calibrate it to match the hand’s physical motions and forces, in real time. However, may several stimulation templates exist that can match the desired hand motions and grasp forces properly. Therefore, we would like to find the ways to optimize the stimulation templates and to get the most optimal control strategy possible. The optimal control strategy would include less electrodes and electrical stimulation to obtain the best results, the more natural way to control the assistive devices, the more desired function produced, etc. In this paper, we showed the methods to find targeted muscle profiles and to create stimulation templates. Although we just have normal subjects to test our algorithms, we will arrange the SCI patients to study further in the future. It surely has the importance to find the optimal strategy of patient-driven
command controller for quadriplegics by function electrical stimulation. We will have more research and work done in the near future.

References

[2] Ying-Han Chiou, Ruei-Shr Tzeng, Jin-Shin Lai, Te-Son Kuo, A digital signal processor based functional electrical stimulation system with its user interface design. 2nd Joint EMBS-BMES Conf., 2002

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