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Rehabilitation Using a Data Glove for Moving the Paralyzed Fingers

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We have synthesized spinnable carbon nanotube (CNT) [1] and have developed the CNT strain sensors as components of a textile based, wearable sensing system for real-time motion detection [2]. Well-aligned CNT sheets are fabricated by stacking and shrinking the CNT webs. Experimental CNT strain sensors are manufactured by placing the CNT sheet on a flat and smooth substrate in a direction parallel to the stretching direction and impregnating it with elastomeric resin. The sensor resistance is proportional to the applied tensile strain that increases with the applied force. The temporal strain changes are closely followed by the variation of the strain sensor resistance that can exceed 200 %.

We have developed a data glove using the CNT strain sensors [2]. The data glove is a wearable device with incorporated the strain sensors that allow for motion and posture tracking of the user's hands and fingers. Since direct sensing is employed, there are no environment restrictions and timely, highly reliable data can be collected. Motion interactions are then implemented through real-time analysis and recognition of the user's hand and finger posture and gesture.

In this study, we have applied the data glove to functional electrical stimulation (FES) training [3]. FES is used to restore motor function in paralyzed patients because of stroke or spinal injury. In FES, electrical stimulations activate nerve tissue connected to muscle groups to contract muscles to induce movement of the hands. Its restoration improves the quality of life of a paralyzed patient, because hand function is crucial in daily life. We have proposed an FES training method triggered by motions of the opposite hand. Symmetrical motions in the target hand are triggered by the response to multiple motions of the opposite hand. The posture of the opposite hand is recognized by a data glove, and the electrical stimulation points of the multi-pad electrodes of the target hand are dynamically selected on the basis of the recognized posture. The patient can make the target hand produce postures symmetrical to the multiple grasping postures of the opposite hand without being aware of a special device. Electrical stimulation points that elicit the desired grasping motions are explored in advance with reference to the postures of the opposite hand. The proposed method can be applied to contralaterally controlled functional electrical stimulation (CCFES) and a combined method of mirror therapy and FES to train paralyzed patients to recover their grasping function more effectively.

Figure 1 shows the experimental flow (upper) and the target grasping postures and a relaxed open posture recorded with the opposite hand (lower). The experiment was conducted as follows: In step 1, multiple grasping postures were recorded with the subject's opposite (right) hand using the data glove to create a data table for identifying hand posture. In step 2, the stimulation electrodes of the subject's target hand were scanned, and the optimal stimulation electrodes to produce the pre-recorded target grasping posture were determined by detecting the evoked postures with the data glove . In step 3, symmetrical postures were produced in the target (left) hand. Specifically, the grasping posture of the opposite hand was detected with the data glove. Then the optimal electrical stimulation pattern identified in the search was applied to the target hand according to the discriminated grasping posture. This procedure produced symmetrical postures in the target hand in response to the grasping postures of the opposite hand.

In summary, we have developed a system that combines multichannel FES and a data glove with CNT strain sensors. Experiments on four healthy subjects demonstrated that the system selectively activates the muscles of the target hand in response to the grasping postures of the opposite hand. Additionally, the method produces postures symmetrical to those of the opposite hand. By this method, patients can intuitively train multiple grasping motions using FES without operating special

instruments. Applying this method to CCFES or its combination with mirror therapy should improve the efficacy of training with FES.

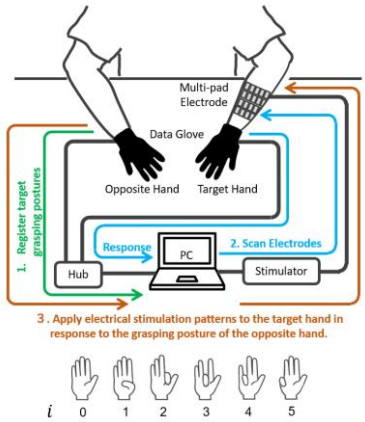

Fig. 1. Flow of the three steps of the experiment (upper) and target grasping postures and a relaxed open posture recorded with the opposite hand (lower).

References

1. Y. Inoue, K. Kakihata, Y. Hirano, T. Horie, A. Ishida, and H. Mimura, Appl. Phys. Lett. 92 (2008) 213113.
2. K. Suzuki, K. Yataka, Y. Okuyama, S. Sakakibara, K. Sako, H. Mimura and Y. Inoue, ACS sensors (2016) 817.
3. S. Takigawa and H. Mimura, Sensor and Materials 33 (2021) 3645.