A study of simple adaptive control system of electrical stimulation for upper limb motion

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Abstract—Functional electrical stimulation (FES) is known as a technique for restoring lost motor functions in paralysis patients. In this study we developed an FES controller by employing simple adaptive control (SAC), and verified it on a young healthy man. The controller did not need the complicated adjustment.

I. INTRODUCTION

Functional electrical stimulation (FES) is known as a method for restoring lost motor functions in paralysis patients by giving an electric stimulus from the outside that yields a muscle contraction. The authors are developing an FES system that restores arbitrary movements of paralyzed upper limbs. In a previous study, we proposed an FES system that uses a disturbance observer and PD control to apply control in the vertical plane of an elbow joint [1]. The system was designed for engineers, not medical staff and ordinary patients; consequently, this implies that its usability decreases if the adjustment of parameters becomes complicated. In this research, we develop a controller by employing simple adaptive control (SAC). The developed controller does not need a complicated parameter adjustment [2].

II. SYSTEM

Figure 1 shows the composite of our upper-limbs FES system. The upper-limbs FES system consists of a digital signal processor (DSP), an electric stimulator, electrodes and a potentiometer. As shown in this figure, the elbow joint angle is measured by the potentiometer, located under the upper arm and fixed with an elastic strap to the upper torso. The intensity of the electric stimulus for restoring a target movement is determined by the DSP based on the measured angle. Then, stimuli are applied by the electric stimulator to the biceps and triceps brachii muscles through the electrodes attached on the skin of the upper arm. When the stimulus is applied, the muscle contracts and the forearm rotates at the elbow joint.

The designed control system, shown in Fig. 2, is the cascade control with a speed control system and a position control system. When the control plant is almost strictly positive real (ASPR), the control plant can be stabilized to some extent by the output feedback with large constant gain. SAC is an adaptive control technique that uses this property.

Since the control plant (in this case, the upper limb) needs to be ASPR to apply SAC, we put a pre-compensator in the control system and enable ASPR on the transfer function from the command joint angular velocity to the real joint angle. Then, we are able to apply SAC to the position control system of the major loop by making the ASPR-enabled technique be a minor loop.

III. EXPERIMENT

We verified the validity of the developed FES system with SAC by forearm control of a young healthy man. The experimental result is shown in Fig. 3. Though we observed a small variation at the beginning of the target change, the variation disappeared rapidly by the effect of SAC, and the joint angle closely followed well to the target angle. From this result, the developed system with no complicated parameters adjustment achieves good control performance.

REFERENCES