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EXPERIMENTAL IMPLEMENTATIONS OF ADAPTIVE SELF-ORGANIZING FUZZY SLIDING MODE CONTROL TO 3-DOF REHABILITATION ROBOT

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Abstract. *Since the 3-DOF rehabilitation robot actuated by pneumatic muscle actuators (PMAs) has highly nonlinear and time-varying behavior due to gas compression and nonlinear elasticity of bladder containers, it is difficult to establish an accurate model for designing a model-based controller. Here, this study proposes a novel adaptive self-organizing fuzzy sliding mode control (ASOFSMC) to improve control performance. First, the fuzzy sliding surface is established to reduce the number of fuzzy rules. The self-organizing learning mechanism is then employed to modify on-line fuzzy rules, and the model-matching technique is adopted to adjust the scaling factors without the need for trial-and-error. Finally, the stability of the proposed ASOFSMC is proved by using the Lyapunov theory. Experimental results further verify the effectiveness of the ASOFSMC in various commands for a 3-DOF rehabilitation robot.*
Keywords: Pneumatic muscle actuator, Rehabilitation robot, Fuzzy sliding surface, Self-organizing learning mechanism, model-matching technique

1. **Introduction.** Rehabilitation devices provide joint loading to help patients recover extremity functions in cases of traumatic brain injury, amputation, bone injury, or spinal cord injury caused by traffic accident or cerebral apoplexy that affects activity of the extremities. Physiotherapy for achieving functional rehabilitation is normally provided by medical therapists on a person-to-person basis, but automatic equipment has also been employed in physiotherapy programs. However, traditional rehabilitation devices are usually driven by electric motors, which are typically rigid in nature. Hence, actuators may cause discomfort or even pain during continuous passive movement when interfacing with humans. Ideally, rehabilitation robots should offer high levels of safety and flexibility for humans. In view of this, submissive pneumatic muscle actuator is best suited for application to rehabilitation robots to minimize pain or discomfort incurred on users.

The behavior of a pneumatic muscle actuator (PMA) is very similar to the muscle of an animal. The advantages of a PMA include high power/weight ratio [1], high power/volume ratio [2], low cost, low maintenance expense, cleanliness, flexibility, and great compliance. Therefore, it is fitting for use in rehabilitation engineering that requires great safety for patients suffering from lesion of neural muscles or skeletal muscles, which affects the functions of their limbs. Nonetheless, pneumatic compressibility and many non-linear phenomena of plastic tube and flexible fiber pose problems in achieving excellent control performance. To overcome these problems, several control theories have been developed.