Advanced Rehabilitation Device Based on Artificial Muscle Actuators with Neural Network Implementation

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Abstract:

In this paper the rehabilitation device for upper arm based on artificial muscles is introduced. Presented automated rehabilitation device has three degrees of freedom: 2 DOF in arm and 1 DOF in elbow that provides almost all basic rehabilitation exercises. Artificial pneumatics muscles will be tested in connection with spring and antagonistic connection. This system provides lifting and falling of arm construction based on patient force. There is possibility to generate help force during rehabilitation or opposite load. Artificial muscles are controlled by pneumatic valves terminal from micro computer based on MCU. Higher level control system provides artificial intelligence implementation based on neural network for prediction and change of load according sensor values history (incremental sensor, pressure sensor). For prototype testing there is described usability of industrial robot to test precision of load and trajectories during rehabilitation. This automatic rehabilitation device will help to reduce therapeutics work with patient, automate and improve rehabilitation process.

Keywords: *rehabilitation, automation, artificial muscle, control*

1. Introduction

Automated rehabilitation is nowadays in fast development in physical therapy [3]. Automated rehabilitation is a special branch of rehabilitation medicine focused on devices that can be used by people to recover from physical trauma. The first results in this area are described for example in these articles [5], [6]. Automatized machines are very suitable for implementation to rehabilitation area. They replace manual procedures by autonomous exercises. There are three main areas of physical therapy: cardiopulmonary, neurological, and musculoskeletal. Though automated rehabilitation has applications in all three areas of physical therapy, most of the work and development is focused on musculoskeletal uses. Musculoskeletal therapy assists in strengthening and restoring functionality in the muscle groups and the skeleton, and in improving coordination. In the current paradigm of physical therapy, many therapists often work with one patient, especially at the early stages of therapy. Automatic rehabilitation allows rehabilitation to occur with only one therapist, or none with adequate results. Automated systems allow more consistent training program with automated tracking patient's progress and shifting the stress level accordingly, or making recommendations to the human therapist. In the future automated rehabilitation promises effective results. As the technology develops and prices decrease, rehabilitation systems will be available in everyday life.

2. Construction

Construction of prototype device is mainly based on standardized aluminum profiles and rotary joints. All actuators are based on pneumatics artificial muscles. Artificial muscles are suitable for these devices because of their flexibility especially in end positions. Presented automated rehabilitation device has three degrees of freedom: 2 DOF in arm and 1 DOF in elbow that provides almost all basic rehabilitation exercises as it was described by [1]. Artificial pneumatics muscles will be tested in connection with spring and antagonistic connection according design [4]. This system provides lifting and falling of arm construction. Possibility to generate help force during rehabilitation or opposite load is there. Artificial muscles are controlled by pneumatic valve terminal from micro computer based on MCU. Higher level control system provides artificial intelligence based on neural network for prediction and change of load according sensor values history. Simplified kinematics scheme of rehabilitation device is displayed in Fig. 1.

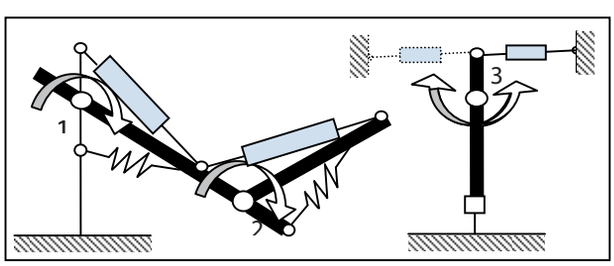

Fig. 1. Kinematics scheme of rehabilitation device

The mechanism is fixed to double chair for rehabilitation in a comfortable sitting position. Rehabilitation system is designed for both arm (left, right), but not in same time. The patient must change chair for adequate arm.

3. Control system

The main control part is based on 8bit MCU (ATMEGA128L microcontroller) which control pneumatics artificial muscle and cooperate with sensors, detailed scheme is pictured in Fig. 2. The main output part for switching the electromagnetic valves is integrated transistor array, which is directly connected to the microcontroller output. Device is equipped by display and keypad for monitoring of rehabilitation process and practices selection. Microcontroller communicates with a PC by serial link (US-

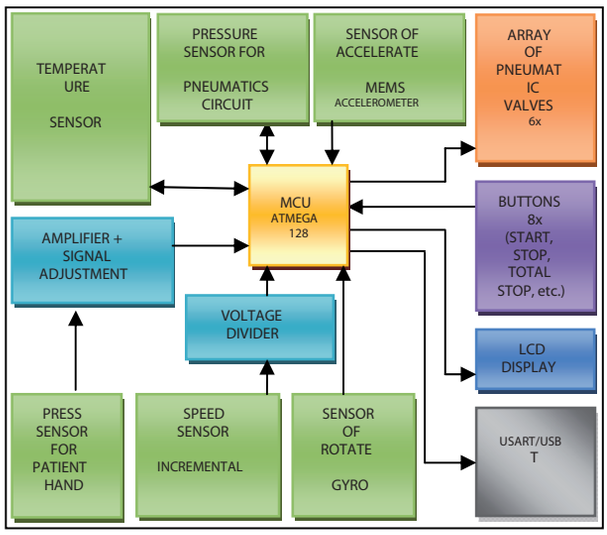

Fig. 2. Principle scheme of control system

ART). There is possibility to connect device to mobile PC by USART to USB transducer.

The basic control algorithm for the control of the rehabilitation process consists of three parts:

a) Regulatory part,
b) Protective part,
c) User part.

The regulatory part of the algorithm ensures that the rehabilitation device copying required trajectories. An important feature for controlling the rehabilitation is pressure sensing of patient arm. Based on this property we can achieve a suitable speed of shoulder rehabilitation practices in the prescribed mode.

The protective part of the algorithm is designed to ensure safety of the patient during rehabilitation exercises, where for example: in case of detecting of acceleration level over the certain threshold device has to stop the movement of limb within a few milliseconds. The important elements for detection is included acceleration sensor, gyroscope and temperature sensor of human body (to monitor of the muscles during practice).

The user part of the algorithm ensures communication between the user and the microcontroller. There is possible to choose several types of rehabilitation practices with various parameters. All data during practice are displayed on the display unit. Main display is not able to display all values at once, so individual information rotated cyclically in a time loop [7].

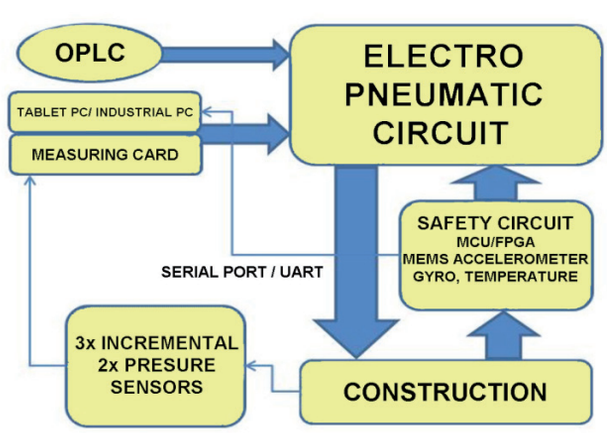

Fig. 3. Diagram of Rehabilitation Control System

Diagram in the Fig. 3 illustrate rehabilitation device control system for first prototype with external measuring card and description of safety circuits. High level control system is based on Industrial PC alternatively OPLC or Tablet PC with additional information from testing sensors.

4. Neural Network implementation

Utilization of artificial intelligence is widely applied in present. There are many experiments with various algorithms, methods and their combination e. g.: neural networks, theory of learning machines (machine learning), fuzzy logic, genetic algorithms, experts systems etc. As it was mentioned above the pneumatic artificial muscle is now unused mostly in reason of complicated control because of there is high non-linearity.

Standard types of regulator fail what is main reason of using neural networks. Sequence of operation is visible in the Fig. 4 on the left. It describes operation of rehabilitation device. In diagram is rehabilitation device represented by operation system. In the Fig. 4, right there is displayed neural network with assigned specific values of four inputs to one output important for correct function NS. There is used NS with back propagation teaching.

Proposed NS has been able to learn with acceptably mistakes of learning in less than 80 cycles. After leaning NS there is next step to create tested set of data. After creating tested set of data there was tested NS and interpretation of testing NS. Interpretation is running on basis of comparison real and expected results of classification.

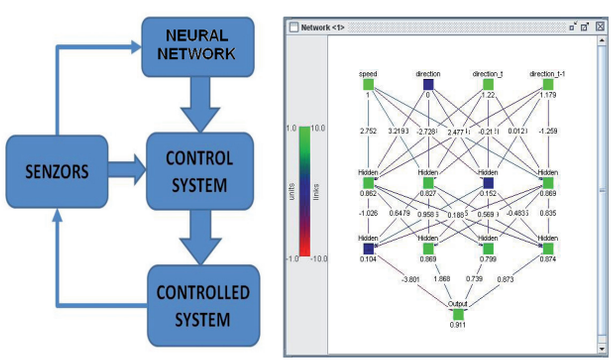

Fig. 4. Neural network and control scheme of implementation

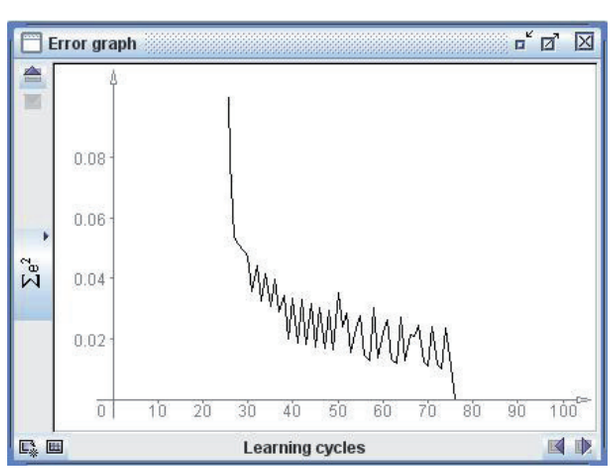

Fig. 5. Neural network and control scheme of implementation

It is defined some of coefficients of estimate precision of classification. All vectors were classified correct. So it sit about aptitude of application NS in rehabilitation device. In Fig. 5 is displayed Error graph of created neutral network.

5. Industrial Robot testing System

Testing platform is based on articulated robot with 5 DOF Mitsubishi RV-2AJ [2]. The robot is controlled from external C# application and serial port. Rehabilitation device is connected to end component of robot by flexible coupling. We can reach any position in 3D robot workspace to define testing trajectory easy in drawing area. Testing device can help check safety of rehabilitation device before testing with life patient. Simulation of testing device and rehabilitation system is displayed in Fig. 6.

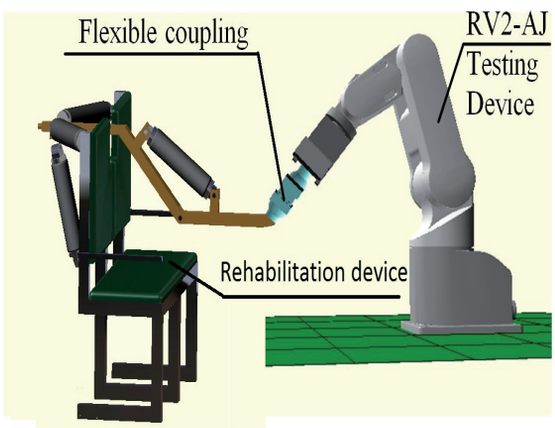

Fig. 6. Simulation of testing device and rehabilitation system

6. Conclusion

The project is using artificial muscle as joint actuator because of silent operation and flexibility during movement, start and end position. The developed automated rehabilitation device will save therapeutics capacity, provide improving in prediction of increasing and decreasing load during rehabilitation exercises according patient progress. System is monitored by many sensors during operation together with low level safety circuit. Prediction of load is based on integrated neural network algorithm. There is designed prototype testing system based on industrial robot. Next works after successful testing process will be development of mobile version without chair as orthosis (exoskeleton) for direct rehabilitation in patient household.

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VEGA-0185-10 Study of power semiconductor converterswith high power conversion efficiency.

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