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TESTING OF REHABILITATION DEVICE WITH INDUSTRIAL ROBOT

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Abstract: *The automatized rehabilitation area is currently in fast development together with rehabilitation robotics. After the device development is done, there is another important task to be accomplished - how to safety test device without patient injuries. This Article is describing one design in rehabilitation testing systems, based on industrial robot. The device is designated primarily for testing rehabilitation device with artificial muscle. The Construction based on artificial muscle is flexible, which enables to test reliability of the device before using it in practice. It is used for positioning articulated robot with 5 DOF Mitsubishi RV-2AJ. The robot is controlled from external C# application through serial port. Rehabilitation device is designed for upper arm rehabilitation and is connected to end of robot efector through coupling. We can reach any position in 3D robot workspace to define testing trajectory easy in draw area. Testing device can help check safety of rehabilitation device before testing with life patient.*

Keywords: ***Automation, robotics, rehabilitation, artificial muscle.***

1. Introduction to rehabilitation systems

The coupling of several areas of the medical field with recent advances in robotic and automated systems have seen a paradigm shift in our approach to selected sectors of medical care, especially over the last decade. Rehabilitation medicine is one such area. Introduction was inspired by articles book from (Kommu et al., 2007). Rehabilitation robotics is a special branch of Rehabilitation medicine focused on devices that can be used by people to recover from physical trauma. Rehabilitation robotics is nowadays in fast development in physical therapy. The first results in this area are described for example in these articles (Furusho et al., 2007; Pons et al., 2007; Sarakoglou et al., 2007). Within the area of rehabilitation robotics the machines are more likely to be used. They replace manual procedures as the possibility of autonomous help is increasing. There are three main areas of physical therapy: cardiopulmonary, neurological, and musculoskeletal. Though rehabilitation robotics has applications in all three areas of physical therapy, most of the work and development is focused on musculoskeletal uses of robotics. 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. Automatized rehabilitation allows rehabilitation to occur with only one therapist, or none with adequate results. Automated systems allow more consistent training program with the robot tracking, patient's progress and shifting the stress level accordingly, or making recommendations to the human therapist. In the future rehabilitation robotics promises effective results. As the technology develops and prices decrease, rehabilitation systems will be available in everyday life.

2. Description of rehabilitation system

In this article, we are going to introduce rehabilitation device for upper arm rehabilitation based on artificial muscle, which will be tested with industrial robot testing device. 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

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almost all basic rehabilitation exercises as it was described by (Sara J. Cuccurullo, 2010). Artificial pneumatics muscles will be tested in connection with spring and antagonistic connection according design (Piteľ J., Boržíková J., 2009). This system provides lifting and falling of arm construction. There is possibility to generate help force during rehabilitation or opposite load. Artificial muscles are controlled through pneumatics block terminals from micro computer based on MCU. Upper control system provides artificial intelligence based on neural network for prediction and change of load according sensor history values. Schematic and design of Rehabilitation device is showed in Fig. 1.

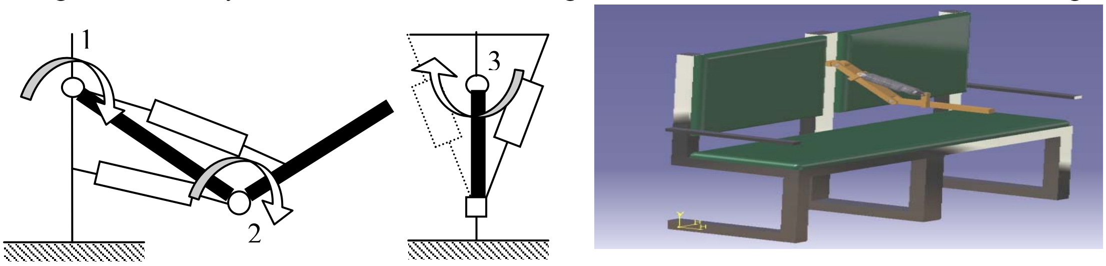

Fig. 1: Scheme of rehabilitation device, 3D design of rehabilitation device.

3. Description of testing device

This particular design of the device was applied because of its ability to be easily modified and used in other application. These special devices are used for short periods of time and therefore their ability to be modified is highly convenient. Another reason why we decided to use Assembly Industrial Robot Mitsubishi RV-2AJ (Mitsubishi, 2007) was that the robot has been easily accessible in our department and we did not need to develop new technology. In addition, the industrial robot is much more precise than rehabilitation device that is next reason for testing usability. Next advantage is auxiliary DOF in efector which can be used to setup angle and position of load. The system consists of industrial robot RV-2AJ, control system CR1, flexible coupling, communicating interface and external control application in programming language C#. Fig. 2 shows block communication scheme of device.

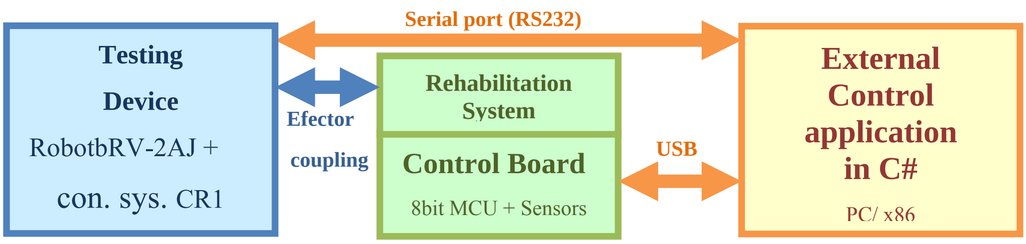

Fig. 2: Communication Block scheme of Testing Device and Rehabilitation Device.

Control Unit CR1 (Mitsubishi, 2007) provides serial port for communication with external application. Testing system is connected to rehabilitation device through coupling with flexible element. Control application is sending information about sequence start, end, ramp time and speed through USB/UART interface. Fig. 3 on the left shows simulated trajectories of testing device for 1 or 2 joint together, Fig. 3 right show first testing of generated trajectories on real device with drawing jig in scale 5:1 to real device. For successful testing and removing deviation from result there is disabled force sensor circuit in rehabilitation device. The speed of rehabilitation device is initialized straight from testing device. Precision of testing device is derived from industrial robot, repeatable precision is ± 0.02 mm.

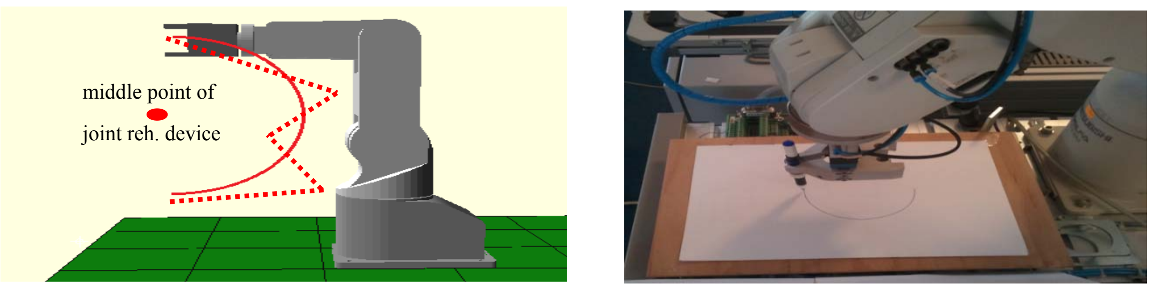

Fig. 3: Simulation of testing trajectories (circular interpolation one joint – red line, linear interpolation two joints together – dotted line), testing of trajectories draw jig.

Procedure of testing is divided to three tests:

1. Testing of one joint: First test of reliability is done on one joint, other two joint must be fixed and speed during whole trajectories will be same. This will be simulating movement of people arm for fluent rehabilitation. There is used circular interpolation.
2. Testing of two joints: We can test any movements in 2D space after successful first test. Two joint will be free and one fixed. Position of free joint is counted through goniometric function. There is used linear or circular interpolation. We can change speed of movement for any segment of linear interpolation.
3. Testing of emergency state: We can test instant stop, ramp start and movement in opposite direction. This test is suitable for testing unpredictable state of rehabilitation device, for example total stop reaction and test overload. This last test is checking states, which can cause injuries to patient during rehabilitation.

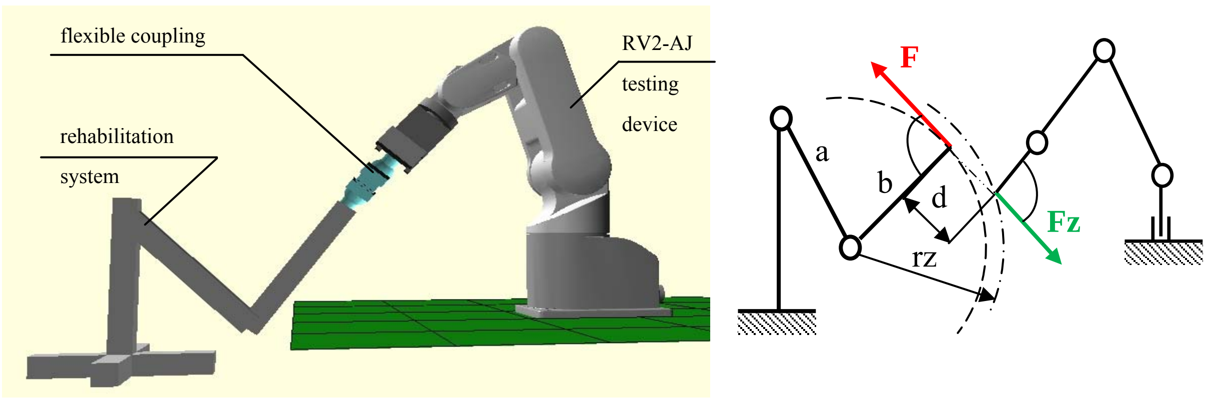

Fig. 4: Simulation of testing device and rehabilitation system, principle scheme of one joint testing.

Simulation of testing device with rehabilitation system showed in the Fig. 4 left. Principle of testing for one joint is showed in the Fig. 4 right. Initial load (force) is created thru flexible coupling element by changing dimension d according equation:

$$d = d1 \pm Fz/k \qquad (1)$$

For circular interpolation we can easy acquire radius of testing device turning:

$$rz = \sqrt{d^2 + b^2} \qquad (2)$$

4. Software part of Solution

Principle of trajectory programming for Industrial robot is primarily based on before known number of Points (Positions). These points are stored to robot memory through teach pendant console. Program is created offline and is loaded to control system through serial port. We need faster and dynamic method for create Robot program and Points definition. That was a main reason for development of new external Robot control application. Our program provides dynamic robot programming. This possibility is defining trajectory by selecting Point in graphic area adapted to Robot workspace. There is possible dynamically change number of cycles. Principle of remote control Robot is using internal system command for control system and command for Robot. There is described minimal sequence for testing device: robot control system activation “1;1;CNTLON.“ and servomotor enable command "1;1;SRVON.". After the initial activation is done, we can use classical commands for robot programming MelfaBasic4, but with command prefix “EXEC”, for example. "1;1;EXECMOV P1". The control program is working remote, that is reason why we must get periodically information about control and robot state, "1;1;STATE“. Request for actual control system state is sent every 100 ms. The program is divided to three tests, which are described in last chapter. We create force (load) before of the program starts. The load is created by flexible coupling. Next step is communication with rehabilitation device. We sent data about testing angular speed to rehabilitation device thru UART. Then we start both devices in same time. Testing output is information about testing device written to text file with information about collision. On the end of cycle there is stored information that trajectories and cycle was successful done. The Fig. 5 shows control application for testing.

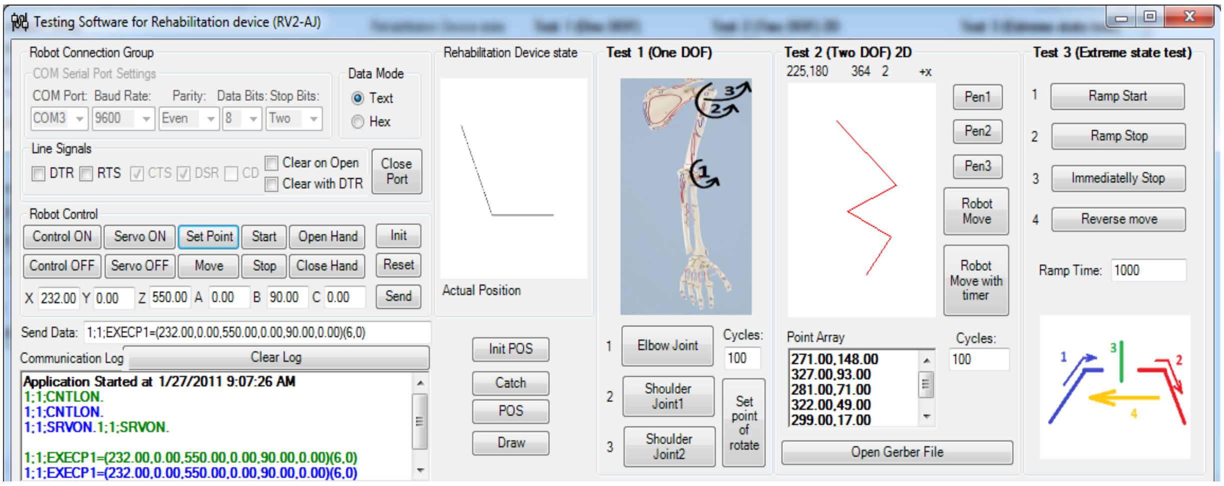

Fig. 5: C# application for testing rehabilitation device.

5. Conclusions

The introduced solution will be used for rehabilitation device testing. The Solution is based on industrial Robot Mitsubishi RV2-AJ. There are three level of testing, first for one joint testing, second for two joints together and third for unpredictable states testing (stop, start ramp, change direction of movement). There is possible to setup number of cycles for any movement. Software solution is using standardized programming language that means there is possibility to use same control application for many robots and control systems. Reliability check of testing system was done with simulation program and trajectories were checked with drawing jig scaled in XY plane. The Current solution only log robot state to text file during movement in fixed interval. Next works on the solution will be implementation database to store complex data (robot state, sensor data) from testing process for next result processing.

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