TESTING OF AUTOMATIZED REHABILITATION DEVICE DESIGNED FOR ELDERLY BY INDUSTRIAL ROBOT

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Abstract

The study describes the possibilities of usage of industrial robots in development and research of rehabilitation positioning facility. Sphere of usage is in the field of rehabilitation centers and it can be either professional or for improving life of older people. An articulated industrial robot Mitsubishi RV-2AJ with five degrees of freedom was used as a positioning facility. Rehabilitation facility is designed for an upper limb and it is connected to the robot with a flexible coupling through the effector. Using this facility we can easy achieve any position in 3D space (workspace of robot) to define a test trajectory in the drawing window. It is possible to change the speed of movement on a trajectory.

Keywords

rehabilitation, robotics, automation, artificial muscle

Introduction

Rehabilitation robotics is a field of rehabilitation medicine and as a special branch of robotics is focused on machines, which can be used to recovery patients after surgery, physical injuries and finally can help even the older people to keep their better condition and health state. Concerned are mainly the older people, which physical and mental functions are reduced by age and persons with the health disability of all age categories. There is several Europeans projects oriented to these older people in order to improve and make easy their life. One of those is program AAL (Ambient Assisted Living) as well. The objective of the AAL Joint Programme is to enhance the quality of life of older people and strengthen the industrial base in Europe through the use of Information and Communication Technologies (ICT). The motivation of the new funding activity is in the demographic change and ageing in Europe, which implies not only challenges but also opportunities for the citizens, the social and healthcare systems as well as industry and the European market. The concept of Ambient Assisted Living is understood as

- to extend the time people can live in their preferred environment by increasing their autonomy, self-confidence and mobility,
- to support maintaining health and functional capability of the elderly individuals,
- to promote a better and healthier lifestyle for individuals at risk,
- to enhance the security, to prevent social isolation and to support maintaining the multifunctional network around the individual,
- to support carers, families and care organisations, [1]

The selected services and applications will be developed with a Design for All approach together with potential users in the following areas:

- Comfort applications: home control, personalised communication interface, activity planning
- Health: monitoring, medication
- Safety and security: safety at home, visitor validation, activity detection
- Communication and information [10]

The branch of rehabilitation robotics could be useful in the given field. Rehabilitation robotics in the field of physical therapy is just in progress, but already achieved some results in this sphere. [2], [3], [4]. Field of rehabilitation robotics is a way, where machines are better than manual techniques and their autonomous ability to help the people is still increasing. Connection of some medicine areas with advanced automated and robotic systems achieved new approach to sector of medical care, special in the last decade. Rehabilitation medicine is one of these areas. There are three main areas of physical therapy: cardio –

pulmonary, neurological and skeletal-muscular. Cardio – pulmonary therapy treats the respiratory problems as asthma, rehabilitate the problems related to cardio trauma. Neurological therapy is mainly focused on recovery of muscles and their support. Skeletal-muscular supports the gain and recovery of functionality in muscular groups and skeleton and improves the coordination. Rehabilitation robotics has applications in all three areas of physical therapy, but most of works and researches are oriented to muscular-skeletal area using robotics. One area of rehabilitation robotics is robotic exoskelet. Advantages of rehabilitation robotics are significant. At current paradigm of physical therapy there are lots of therapists working with one patient treating his limb, mainly at beginning of rehabilitation. Robotic rehabilitation facility enables to rehabilitate adequate together with one therapist or without therapist, whereby the facility provides e.g. support for patient walk. Automated rehabilitation facility enables the more continuous training program with monitoring of patient progress and next lifting of stress level, or offering the recommendations to change the load. Rehabilitation robotics promises effective results in the future. As the technologies are developing and prices are going down, the rehabilitation robotics and its potentialities for people will be available in common life.

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 [11]. 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 [9]. Artificial pneumatics muscles will be tested in connection with spring and antagonistic connection according design [8]. This system provides lifting and falling of arm construction. Schematic of Rehabilitation device is showed on Fig. 1.

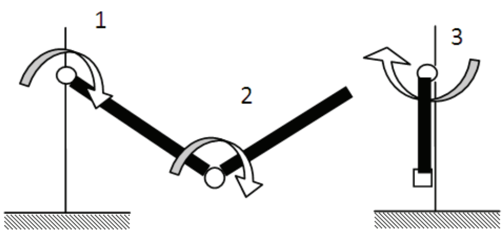

Fig. 1: Scheme of rehabilitation device.

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. Design of Rehabilitation device is showed on Fig. 2.

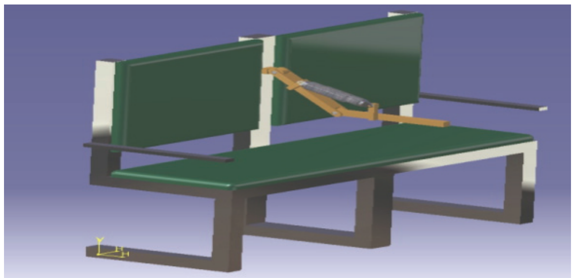

Fig. 2: 3D design of rehabilitation device.

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 [5] 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.3 shows block communication scheme of device.

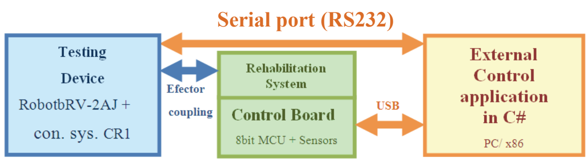

Fig. 3: Communication Block scheme of Testing Device and Rehabilitation Device.

Control Unit CR1 [6] 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. 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.

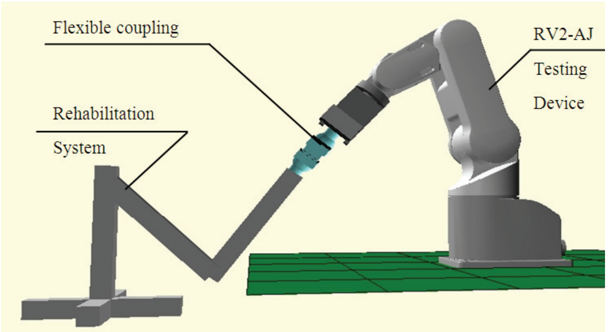

Fig. 4: Simulation of testing device and rehabilitation system.

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.

Simulation of testing device with rehabilitation system showed on the Figure 4. Principle of testing for one joint is showed on the Figure 5. 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:

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

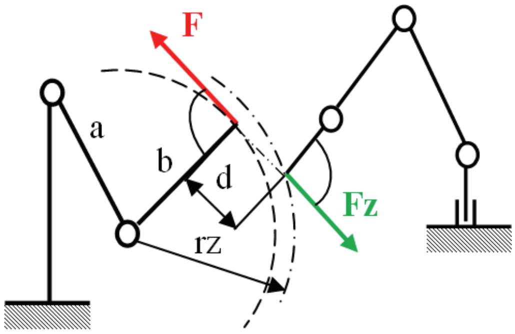

Fig. 5: Principle scheme of one joint testing.

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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