Mechanics and Mechanical Engineering
Vol. 15, No. 4 (2011) 155–163

Manipulator for Rehabilitation with Virtual Reality

Łukasz N. Węsierski
Jacek S. Tutak
Rzeszow University of Technology
The Faculty of Mechanical and Engineering and Aeronautics
Dept. of Fluid Mechanics and Aerodynamics
Al. Powstaców Warszawy 8, 35–959 Rzeszów, Poland
lukwes@prz.edu.pl
tutak_j@prz.edu.pl

Received (16 December 2011)
Revised (17 January 2012)
Accepted (23 February 2012)

Rehabilitation is a very important part of the patient convalescence after different types of accidents or diseases (for example stroke). The basic aim of this process is to remove the motor system dysfunctions. In traditional perception, it takes the form of the cooperation between patient – therapist. But with the technology development it began to appear simple rehabilitation equipment, which task was to support the rehabilitation work. In that time, rehabilitative devices became increasingly complex and they are friendlier to patients and rehabilitant. It began to appear additional modules to stimulate the patient's body to recover quicker. One of these modules is virtual reality (VR), which is described in this article. All of these devices are prepare to accelerate and improve rehabilitation. Additionally they help therapists in their hard and monotonous work.

Keywords: Manipulator, kinematics, dynamics, rehabilitation, virtual reality

1. Introduction

New rehabilitation cannot be based only on devices, which provide only the movement of limb (rehabilitation exercises). The problem of limb dysfunction can be much more complicated. The base of this dysfunction may lie far from the limb. For example after stroke patient has problem with upper and lower limb for one half of body. All of these problems are caused of brain damage caused by the disease. Therefore, it began to appear new modules to accelerate and improve rehabilitation Most popular have become:

– Diagnostics,
– Virtual reality (VR),
– Tele – rehabilitation.

Diagnosis is a very important part of new rehabilitation. It presents numerical information about the current status of the patient, the possibilities of movement and strength. Only in the case of patients who can only passively exercises his limb, diagnostic loses its significance.

"VR base on information technology to create the effect of interactive 3D space. Every object has a meaning (properties) presence in this space" (S. Bryson). The primary purpose of VR is to increase the attractiveness of the process of rehabilitation exercise. From the psychological point of view, VR brings a lot of positive effects like increased patient involvement in treatment or quicker results. It should be noted that it does not want to replace the normal rehabilitation (therapist) but only to help him in his hard work.

Through very good networks of information flow rehabilitation can be developed in the patient's home without the real presence of a doctor or physiotherapist. Tele – rehabilitation reduces costs and increases the number of patients who implement rehabilitation after leaving the hospital. The system consists of modules so that the patient can stay in place A with the rehabilitation unit, monitor, and patient's terminal. In place B is located a monitor and terminal of a therapist or a doctor. In patient's monitor is displayed proposed by the physiotherapist exercises, and the therapist is able to control the current parameters of exercise.

The article focuses in particularly on VR. Special attention is paid to prepare VR for rehabilitation equipment compared to the latest computer games, which we can buy on the market. After an initial analysis we can discover a big difference between this two types of VR. Why there are differences? How does a standard device for rehabilitation with VR module look like? For this type of doubt we want to find an answer in this article. Additionally we would like to note that only a few devices for rehabilitation have VR module.

2. VR in rehabilitation

A good example of application of VR in rehabilitation of the lower limbs is Locomat (HOCOMA company). Hocoma's Lokomat is a driven gait orthosis that automates locomotion therapy on a treadmill and improves the efficiency of treadmill training for people with lower body motor loss (Fig. 1a). This system provides highly intensive, individual training in a motivational environment of constant feedback. This system can be use by children and adults. For children they prepared GABARELLO v 1.0. It is playable prototype of a physiotherapeutic serious game. The interface is a game screen attached to the biofeedback computer of the Lokomat. The game is controlled by the force of the movement of the user in the Lokomat. The patient plays the game during a free time and the same time thus meets therapeutic goals. This system was prepared to stimulate a work of patient's brain. The user is able to anticipate what she or he will do differently next time, and experiences positive rehabilitative effects for the brain as well as the body. One of these games is avatar, which explores the surface of a curious planet. Avatar game is show in Fig. 1b. During this trip he collects objects. When patient plays his exercises very well, avatar changes shape, color and speed of the trip. More intensive collaboration and control of game improves the avatar's abilities [1, 2].

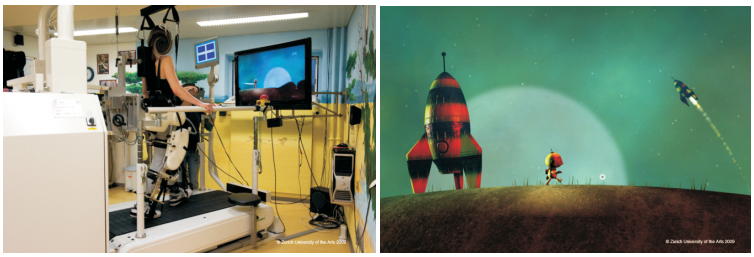

Figure 1 Locomat for upper limb rehabilitation with avatar game [1, 2]

Another example of a system using VR in the rehabilitation is HandTutor (MediTouch company) [Fig.2a]. HandTutor was prepared for upper limb rehabilitation in particularly for hand. The system consists of an ergonomic wearable glove with rehabilitation software. Available games are suitable for a wide variety of neurological and orthopedic injury and disease. HandTutor has a few games prepared for individual rehabilitation. One of these games is "Save the Earth", which help patient to improve the speed of finger movements. The patient receives a motor, visual and audio feedback, which teaches him to understand, plan and carry out the movements of the fingers and wrist [3].

We can also see sets of games that do not have any additional rehabilitation's elements (such as a treadmill or gloves). To control this type of game is done by moving hands, head or any other body part, which movement is detected by the camera. An example of type of these games can be SeeMe developed by Brontes Processing and Beit Rivka Geriatric Rehabilitation Hospital. This system has a few games (including Vulture Strike, Cyclops Ballz, The Vulture Strike FurryMind) and tools for managing a database of patients. Fig. 2b shows an example of the game "The Vulture Strike" which includes: football, volleyball, basketball, wasps, and aircraft [4].

Figure 2 HandTutor for hand rehabilitation with VR (left). SeeMe system with bees game (right) [3, 4]

Sometimes we can find a popular computer game which provides rehabilitation for people who have suffered from stroke or other types of brain injury. The VR rehab system is based on a Microsoft XBox game and the Essential Reality P5 gaming glove, which detects movements of the fingers and wrist and uses them to manipulate on screen objects or characters [5].

Microsoft Xbox can be a typical example of games designed for entertainment. These games were prepared for both children and adults. Fig. 3 illustrates three games: Kinectimals, FIFA12 Revolations and Assassins Creed. The first one is for the youngest, who has to make contact with one of five virtual animals [Fig.3a]. FIFA12 football is a reflection of emotion [Fig.3b]. And Assassins Creed is Revolations journey in the footsteps of legendary mentor Altair on Constantinople [Fig.3c] [6].

Figure 3 Xbox's games: Kinectimals, FIFA12 and Assassins Creed Revolations [6]

3. Differences between VR for entertainment and rehabilitation

The differences between VR for computer game and rehabilitation are connected with a potential user. In each case, the VR has to be interesting. VR for rehabilitation are not so complicated, does not have so many details, storylines, visual and audio effects like VR for computer game. Additionally, one should also keep in mind that sometimes he patient has a problem with the eyes (a field of view) and speed of catching details so it should be reflected in the VR, which should not be as complicated as the computer game. Moreover, sometimes the patient learns to perform movements during the rehabilitation so lower level of complexity of VR has also justification. At the same time the patient very quickly becomes boring during rehabilitation. Therefore, rehabilitation games may not be too long and they should have proper level. All of these aspects are completely irrelevant in the case of VR for computer game.

In most cases, there is a difference in age between patients and the players. The players are mostly young people, while the patients are elderly so it has significance

in VR. Older people didn't grow up with computer. Therefore, some of them have unfounded fears and anxieties of something new. To summarize, VR for rehabilitation does not have to be so complicated because the purpose of VR for rehabilitation and computer game are different. Quite different situation will be in the near future, maybe for the next 10 – 20 years, when potential patient will be person who grew up with the computer. Prospective patients will expect a high level of the VR for rehabilitation or even the same as in current computer games. Therefore, in the near future, major manufacturers of rehabilitation equipment will also need to take this aspect into account. Development of VR must goes hand in hand with the development of mechatronic devices to improve / master an individual process of rehabilitation.

4. Manipulator for rehabilitation – nearest future

VR for rehabilitation, which was presented above is especially useful for patients who require active exercises or exercises with offload. This type of rehabilitation is prepared to refine the precision of the movements. For other patients who have problems with doing even the simplest motion, VR module can be unnecessary. For all patients we develop a special manipulator, which will improve the process of rehabilitation. This system is a combination of realization of exercises with VR rehabilitation. This manipulator provides comprehensive rehabilitation of the upper limb with hand. The major objectives of the project are:

– Rehabilitation of upper limb including arm, forearm and hand,

– Rehabilitation of the left or right limb,

– Passive and active exercises,

– Exercises in the horizontal and vertical plane,

– Biofeedback,

– Virtual reality (VR),

– Friendly software for the therapist and patient,

– Diagnostics, monitoring and analysis of the rehabilitation for patient,

– Safety,

– Appropriate approach to the patient,

– Low implementation cost of this system because the current prices are still too high for most patients.

As we can see, this is an interdisciplinary project because it stands on the borderline of technical and medical issues [Fig. 4]. It presents the issue of rehabilitation and communication between the physiotherapist and the patient.

Interdisciplinary of the project is connected with mechatronic approach to design. In the traditional method of design issues as functions of mechanical, electrical, control or even rehabilitation were designed sequentially. Responsibility for the various stages of the project rests with the different group of engineers and doctors. Mechatronic design presents teamwork at every stage of the project.

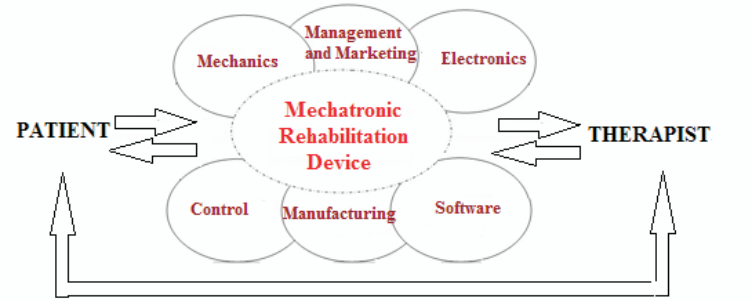

Figure 4 Mechatronic design of the project for manipulator for upper limb rehabilitation

The manipulator for rehabilitation is composed of three basic parts – arms with pads for the upper limb, light frame, drive modules, sensors and the "flash vessel" (the part is responsible for the rehabilitation of the hand, with shape like balloon) [Fig. 5]. In addition, the system consists of friendly software for the patient and therapist.

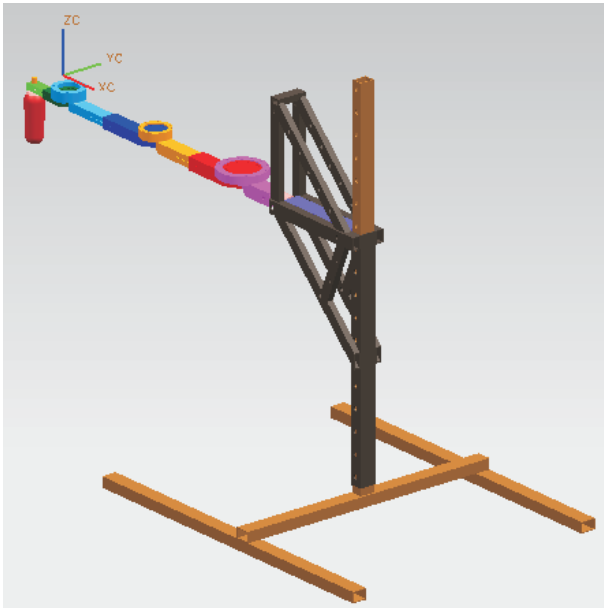

Figure 5 Manipulator for upper limb rehabilitation

Light frame has possibility of different plane of exercises. Therefore it is possible to realize passive or active exercises in the horizontal or vertical plane. In order to find the rated output torque required to drive modules of the manipulator we had to analyze kinematic and dynamic tasks. Fig. 6. shows diagram of the mathematical model for these tasks.

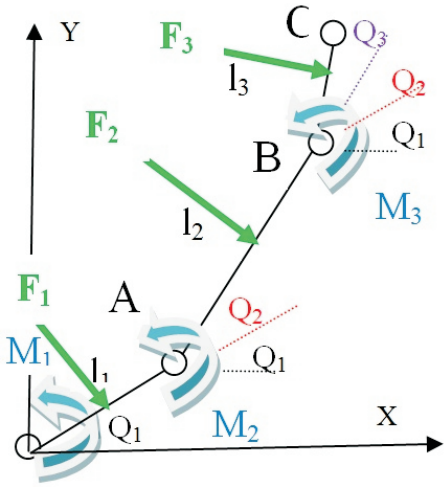

Figure 6 Manipulator for upper limb rehabilitation

Kinematics present motion of manipulator without regard to forces that cause it. Task of dynamics is to present motions of manipulator that result from force. Forward kinematics is the geometrical problem of computing the position and orientation of manipulator's ending given its joint angles. Inverse kinematics gives the desired position of the robot's hand, what must be the angles at all of the robot's joints. Dynamic equations describe the motion of the manipulator associated with driving forces and moments or external forces applied to the manipulator. Dynamic model of the above specification type of manipulator has been derived from using the Euler – Lagrange'a formulation. During this equation there was a problem with spastic forces. In literature we can find some information about spastic forces but they are not suitable for the use in our analysis [8, 9].

For this analysis we selected a sample trajectory, which was realized by physiotherapist and was described as Pascal's snail and the circle. Then we defined the velocity profile. This profile consisted of three parts: acceleration, motion with constant speed and braking. This analysis provides the information necessary for selection servomotors. Fig. 7a shows speed. Fig.7b shows torque.

All of this describes modules (for example VR) are connected with process of adaptation – adjusting to changes in the environment. This process takes place in a natural way in a human body. It starts in childhood when we developed the dynamics of the limb.

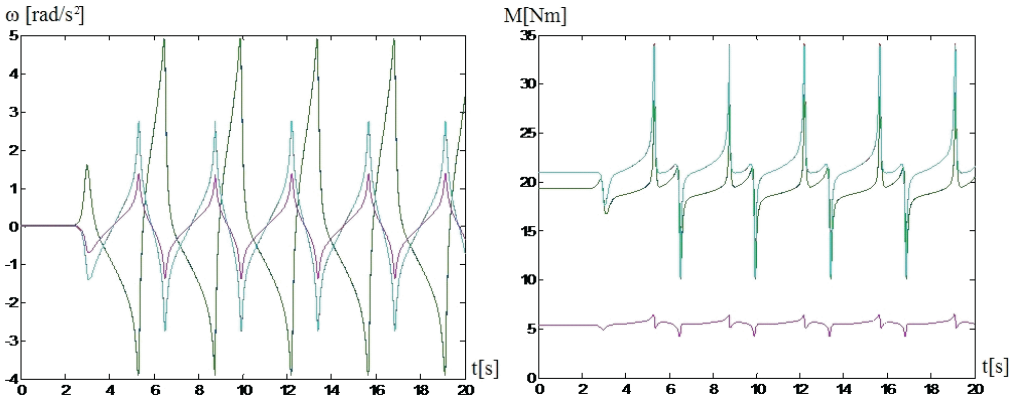

Figure 7 Kinematics parameters ω_1 (green color),ω_2 (blue color), ω_3 (violet color) and dynamic parameters M_1 (green color), M_2 (blue color), M_3 (violet color) [7]

The problem of adaptation in the rehabilitation can be represented in two ways:

- Adaptation by changes in the visual environment
- Adaptation by changes in the mechanical environment.

Also, these two types of adaptation are in our manipulator for rehabilitation. In particularly we want to concentrate on adaptation by visual changes. In future we want to refine elements of mechanical changes too. Very huge problem is possibility to replace or mineralize "touch" of therapist.

5. Conclusion

Our manipulator doesn't want to replace the physiotherapist but this system was prepared to help him in the process of rehabilitation. This interdisciplinary project consists of the following issues: rehabilitation, psychology, marketing and widely understood design process (construction, software, controls, etc.). Thanks of all these treatments connected with mechatronic design, we are able to succeed providing comprehensive rehabilitation for each patient. I want to emphasize that diagnosis and tele - rehabilitation is very important modules especially for the therapist. But for the patient, interesting exercises with VR will enable faster recovery.

Curiosity, passion or even attempt to identify patient with the hero are very important process of rehabilitation. The patient does not think of rehabilitation as necessity but for him, rehabilitation is something fascinating and interesting. VR eliminates monotony and subjective feeling of effort or being tired in rehabilitation. VR always requires additional stimulation of vision, hearing or touch, which is a very positive impact on the process of rehabilitation. We are an aging society. Today VR in rehabilitation is quite sufficient. The question is: does it meet the expectations of tomorrow?

Acknowledgements
This work is subsidized by research grant N N518506039 and "Project is co – financed from the European Social Fund, of the State Budget and Subcarpathian Voivodeship Budget within Subcarpathian Scholarship for post graduate students".

References

[1] **http://www.hocoma.com**
[2] **http://gabarello.zhdk.ch**
[3] **http://www.handtutor.com**
[4] **http://www.nowoczesna-rehabilitacja.com**
[5] **http://neurophilosophy.wordpress.com/2006/08/30/a-virtual-reality-rehabilitation-system**
[6] **www.xbox.com**
[7] **Węsierski, Ł., Tutak, J.**: Manipulator for Upper limb Rehabilitation, *Aktualne problemy biomechaniki*, (05), Gliwice, 171–176, **2011**.
[8] **Baran, B.**: Pomiar momentów siłmięśnia spastycznego, *Konferencja naukowa studentów*, Wrocław, **2004**.
[9] **Kumar, R., Pandyan, A. and Sharma A.**: Biomechanical measurement of post – stroke spasticity, *Oxford University Press on behalf of the British Geriatrics Society*, 35(4), 37–375, **2006**.