Journal of Achievements in Materials and Manufacturing Engineering
International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Interactive rehabilitation of small children with lower limbs dysfunction

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Received 19.03.2014; published in revised form 01.05.2014

ABSTRACT

Purpose: of this paper is to presents a method of interactive rehabilitation based on a mechatronic system supporting psychomotor rehabilitation of children with lower limbs dysfunction.

Design/methodology/approach: The method is grounded on stimulation of senses through image and sound. To achieve this purpose one used modern multimedia solutions in conjunction with an intelligent controlling system. The system controls the degree of the set rehabilitation load as well as measures the child's concentration.

Findings: The proposed method is a kind of contemporary physiotherapy which combines traditional cyclotherapy and stimulation of the child's intellectual development by means of Glenn Doman's improvement method or with the use of music therapy depending on the degree of the child's intellectual development. Therapeutic activities undertaken with the use of the developed equipment may in the case of paresis or paralysis restore the action of the muscles by improving their elasticity or increasing their ability to react to stimulation of the nervous system.

Research limitations/implications: The combination of movement therapy with psychological stimulation enables the children to use their abilities more efficiently and speeds up the rehabilitation process.

Practical implications: The application of the equipment in question increases efficiency of the therapists' and parents' actions, being at the same time a vital element supporting the laborious and painstaking process of rehabilitation of little patients.

Originality/value: The method consists in movement therapy combined with simultaneous psychological stimulation of the child.

Keywords: Biomechanics; Rehabilitation; Kinesiotherapy; EEG sensor

Reference to this paper should be given in the following way:

I. Chuchnowska, A. Sękala, A. Dobrzańska-Danikiewicz, Interactive rehabilitation of small children with lower limbs dysfunction, Journal of Achievements in Materials and Manufacturing Engineering 64/1 (2014) 20-26.

METHODOLOGY OF RESEARCH

1. Introduction

The rehabilitation of disabled children with motor and intellectual impairments is a multidirectional activity to restore, as far as possible, a sick child's ability to independent life in the society, to learning or to achieve substitute abilities which could compensate particular functional losses. Child rehabilitation must be adjusted to children's needs and, most of all, abilities. It should comprehensively consider neuropsychological, motor and cognitive aspects. The main aim of rehabilitation for a child is to acquire the activities and skills appropriate for one's age. When conducted appropriately, it should become part of a child's everyday life, learning and play. The form of work with a disabled child depends, among others, on the possibility of establishing a contact with the child and instructions being carried out by a child in a conscious way. This is often impossible or very limited, especially with youngest children, and special rehabilitation methods using a responsive activity need to be employed. Rehabilitation must not discourage a child from further work and should not be associated with pain. The rehabilitation of children with motor organ defects is a complex process in which psychological therapy also plays a major role. Physiotherapy improvement activities for young children should be undertaken immediately after discovering a defect. Such activities should be targeted at the final result, i.e. restoration of independent walking and using, as far as possible, natural capabilities of young children's brain development, which is essential, as it is often factoring the length and quality of such patients' life. Psychomotor stimulation, when applied early enough, may prevent or at least reduce incorrect forms of posture, movement and behaviours. The main aim of rehabilitation for a child is to acquire the activities and skills appropriate for one's age. Unfortunately, without stimulating child attention adequately, one's involvement is fading very quickly as the child is become more and more bored with cyclical exercises. Very helpful in attaining rehabilitation goals for children are various types of technically assisted instruments which – apart from fulfilling the basic tasks resulting from their intended use – are also very important in making rehabilitation more attractive, make the child more interested and allow to perform different activities longer with less fatigue. It hence becomes necessary to render the process of improving and deploying innovative methods of therapy assisted with modern technical instruments more effective and such methods can be created by combining kinesitherapy, neurophysiology and engineering. From a medical perspective, the earlier a child rehabilitation process is commenced the easier and faster it will be and more therapeutically successful. By using the correct physiotherapy procedures and supporting rehabilitation instruments as early in life as possible, the children undergoing rehabilitation can acquire such skills as independent walking, thus helping them to handle the basic daily activities, which is improving the quality of their life.

The article proposes a concept of a new form of psychomotor therapy for young children with a dysfunction of lower limbs. An important element of the developed concept is a design of a mechatronic rehabilitation device using an EEG sensor. The rehabilitation device has been developed in the same way to enable versatile rehabilitation and stimulate a child's physical and, most of all, psychic development, while enabling at the same time the child's parents and closest environment to conduct such a therapy, with only some substantive supervision of persons educated in this filed. The method concept developed, together with a specialist device, allows – in relation to revalidation of children with motor impairments – not only for their fuller development but also creates conditions for independent, though supervised work. The effectiveness of therapists and parents' activities can be considerably improved by using the designed device, while at the same time substantially supporting a tedious and, most of all, difficult process of physiotherapy for young patients [1-9].

2. Method of interactive physiotherapy

Considering that movement influences the exercised part of the body as well as the entire human organism, especially an organism in its stage of development – mainly by gathering new experiences and acquiring more complex motor skills – a child's psychic development is possible. The mutual interaction of two elements on each other is so high that it is difficult to consider them separately in the earliest stage of life and they are always evaluated aggregately as a child's psychomotor development. Cyclotherapy is a form of physical exertion applied to improve motor activity, cardiovascular system and breathing by riding a rehabilitation bike. The method is applied by people with various motor ailments, neurological disorders, with paresis after brain strokes and vertebral core paresis, as well as balance disorders. Such type of rehabilitation is beneficially influencing the balance of a psychic function and neurovegetative disorders and redues fat tissue without excessively burdening the cardiovascular system. A training bike is a tool allowing to

maintain the right pace of training throughout its entire duration. Games and play are the most effective form of exercises for young children. The merger of traditional cyclotherapy with Glenn Doman's physiotherapy method or with music therapy, depending on the level of a child's disability, allows to shapen visual analysis and synthesis, perception and concentration more effectively, develops a skill of self-control and also mobilises and encourages to action. Children are not only learning faster when interactive boards are used, but the whole therapy process becomes fun for them. By gradually increasing task difficulty according to a child's abilities and by rewarding, the therapy proposed can be much more effective than a traditional one (based usually only on suggestions and motivation of children by their caretakers or trainers). By merging interactively the functions of motor physiotherapy with stimulation of a child's intellectual development, cognitive functions can be aided along with cause-and-effect reasoning, stimulation of senses, as well as with improvement in motor coordination and spatial orientation. A physiotherapist, depending on a child's disability level, can select device parameters appropriately (rotation speed of pedals, multimedia contents [10-12].

2.1. Method assumptions

The mechatronic system presented in this work supports the children's rehabilitation process by "play and learn" activities, which is essential to their development At the same time a psycho-motor stimulation of the body takes place. The main components of the system (Fig. 1) are as follows: a children's tricycle, drive and control system, EEG sensor, stationary PC and multimedia display. The child under rehabilitation is subject to the following external stimulation: by means of their eyesight and hearing they receive multimedia transmission, while the rotary

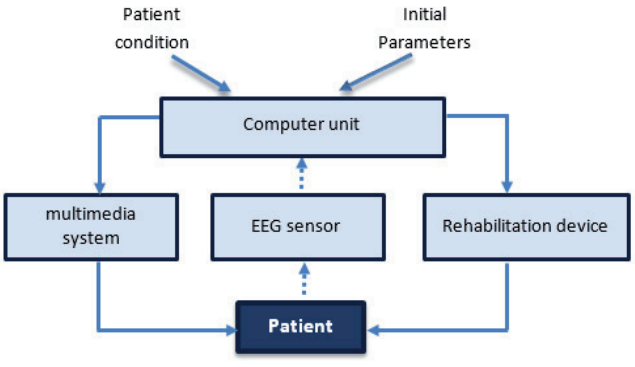

Fig. 1. A general schema of the system

movement of the tricycle pedals activates their muscular and skeletal system. The measurement system of the brain activity was applied here in order to intelligently control the degree of the child's interest in the process of rehabilitation. On the basis of the obtained electroencephalogram (EEG) one assesses the degree of the child's concentration. The achieved level of concentration is further used as feedback in the control loop of the change of multimedia content. The movement of the limb registered by means of the engine control system will generate a certain reaction on the synoptic screen connected to the master control unit.

The main purpose of the exercises performed on the device designed is to rebuild the potential of muscle strength of lower limbs and to improve motion range in joints, which are smaller due to a disorder. Two types of exercises can be practised with the considered device depending on a disability level of a child: passive exercises – pedal movements are forced with an external force, and active exercises – pedal movements are forced with the strength of leg muscles. Feedback containing sound and visual information is used in each of the considered cases. Note that a therapist is responsible for exercise selection and intensity. Moreover, therapy needs to be interrupted if any pain occurs when doing exercises [13-15].

2.2. Control structure of the rehabilitation device

Requirements for a control system of a mechatronic physiotherapy device are implicated by the form of rehabilitation adopted. Adjustable rotation speed of pedals during passive exercises and braking moment adjustment for active rehabilitation are very important features suggesting whether the therapeutic session undertaken is conducted correctly. Another significant requirement is to ensure an appropriate standard of patient safety. It is achieved in a control loop by introducing the control of overloads and responding adequately to the risk occurring. A control system structure of the robotised rehabilitation bike has been established based on the requirements identified, as shown in Fig. 2.

Physiotherapy exercises parameters for lower limbs determined by a doctor or physiotherapist are the input data for an automated rehabilitation process in the global control system setup shown in Fig. 2. Such data provides information on the rehabilitation type (active, passive) and on parameters describing rotational speed of pedals or moment of resistance which is resisting the movements of lower limbs carried out by a patient. A physiotherapist inputs data on therapeutic exercises via the developed

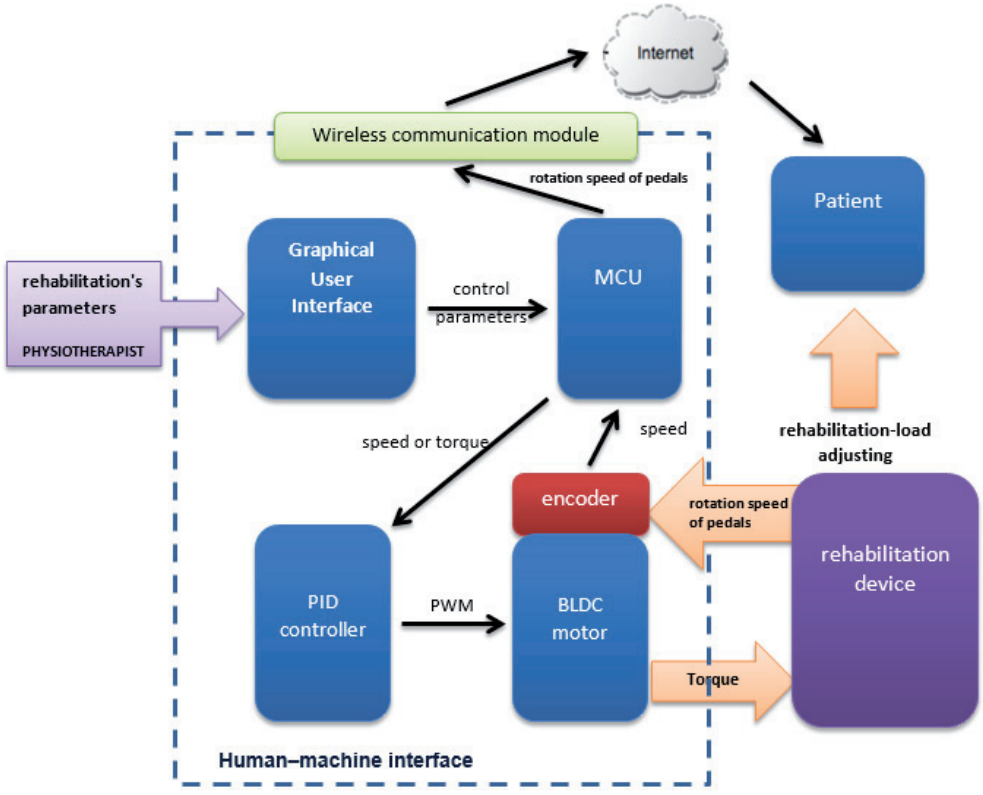

Fig. 2. Control system structure of mechatronic rehabilitation device

Graphical User Interface (GUI). A GUI is a computer programme using graphical elements such as windows, buttons or selection fields. The programme is incorporated within a microcontroller (MCU) using software libraries of an MCU central unit and is displayed on a screen. The GUI's basic task is to parameterise the parameters easily and ergonomically and to control the rehabilitation process by a therapist. A microcontroller is the basic calculation and control unit. A microcontroller is a small and cheap single-circuit computer designed for executing defined tasks, e.g. light control, measurement of analogue values or direct communication.

Wireless data transmission in the mechatronic rehabilitation bike was implemented through the Internet network. An Ethernet controller incorporated into the microcontroller and the UDP protocol (User Datagram analogue-digital converter and the data is then processed Protocol) for the exchange of measuring data was used for this purpose. Figure 3 shows a flow chart of wireless transmission of rehabilitation bike measuring data.

The microcontroller acquires measuring data from an (noise filtration) and a patient's pedalling speed is then calculated by knowing the characteristics of the torque

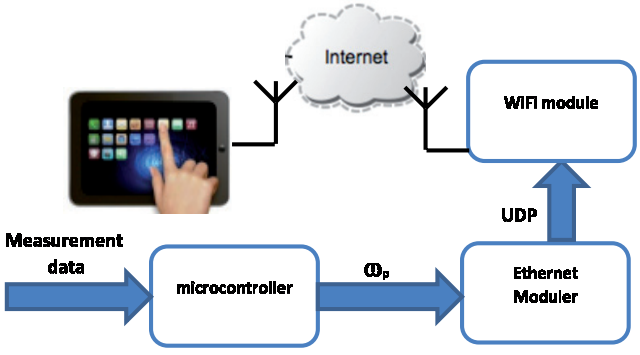

Fig. 3. Flow chart of wireless transmission of rehabilitation bike measuring data

transmission system. The Ethernet controller is establishing internet connection in the next step through a number identifying the rehabilitation bike in the Internet network and the port number on which the data is made available. A WiFi module is used for accessing the information acquired in a wireless mode. A WiFi is an electronic device enabling to build wireless networks operating at the 2.4 GHz band with a range of more than ten metres. The role of a WiFi

module in the control system of the robotised rehabilitation bike is to establish an access point for clients and wireless transmission of data with the UDP Internet protocol. A client is not linked to a server in order to receive data sent by the UDP technology, but data listening is only performed on a defined port. Data packets containing pedalling speed are sent with the frequency of 1 per second and then such parameters are received by a client with algorithms creates in ActionScript programming language by Adobe.

2.3. Device control algorithm

The physiotherapy of child motor organs with a rehabilitation bike is a process in which muscles of lower limbs are cyclically stimulated to action.

The results of electromyography examinations indicate that the greatest activity during cyclotherapy is exhibited by hip flexors and extensors, knee flexors and extensors, foot sole flexors and foot dorsum flexors. Increased activity of lower limb muscles is growing according to pedalling speed and moment of resistance. An advantage of rehabilitation aided by a stationary bike is that a hip, knee and ankle joint is relieved. It is of crucial importance for patients suffering from dysfunctions of the muscular and skeletal system of the lower limb. It is required in a correctly performed rehabilitation process to be able to adjust parameters influencing a therapeutic process. It is very important to correctly select rotation speed of pedals which are conveying a rehabilitation load on the leg muscles, as well as a level of the moment of resistance applied. The parameters of a correctly conducted therapeutic process of a motor organ dysfunction are determining the rehabilitation control algorithms. Figure 4 presents a passive rehabilitation control algorithm.

A process of passive physiotherapy exercises is started by setting constant rotation speed of pedals in a graphical user interface. The set crank mechanism speed is determining an angular speed of a BLDC rotor. Rehabilitation parameters are saved in a microcontroller memory upon defining rotor speed and a therapeutic process is started. A motor overload triggering condition is checked in each control loop. The intensity of the current flowing via a stator winding is measured and when a maximum value is overrun, voltage supplying the motor is disabled. The overload is identifying dangerous situations threatening patient health. The safety system detects whether a child foot is stuck between a bike crank and frame. A decision made by a physiotherapist on completion of the planned exercises is a factor decisive for finishing passive rehabilitation.

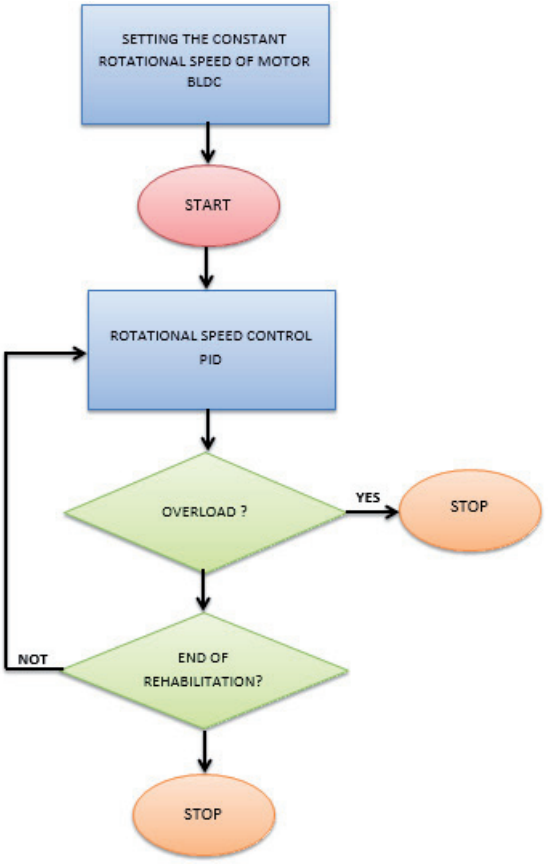

Fig. 4 . Passive rehabilitation control algorithm

An active rehabilitation process is carried out provided the patient is not assisted in the exercises being performed. Figure 5 presents an active rehabilitation control algorithm.

The rotating speed of the motor rotor is set to zero in the first step of the physiotherapy process. Then, a physiotherapist, via a graphical user interface, is setting a load level equivalent to the braking current intensity. The above parameters are stored in a microcontroller memory prior to starting a therapeutic session. The motor rotor speed equal to zero and the set braking current intensity mean that a motor shaft can be moved freely, but is inhibited with electromagnetic torque created in an air gap. Wireless transmission of pedalling speed is carried out upon starting physiotherapy exercises and setting the bike crank into motion by a patient. This information provides input data for a computer game whose basic aim is to encourage a child to perform rehabilitation exercises. A physiotherapist is deciding whether to end a patient's lower limb physiotherapy process by pressing a motor power shutdown button [16].

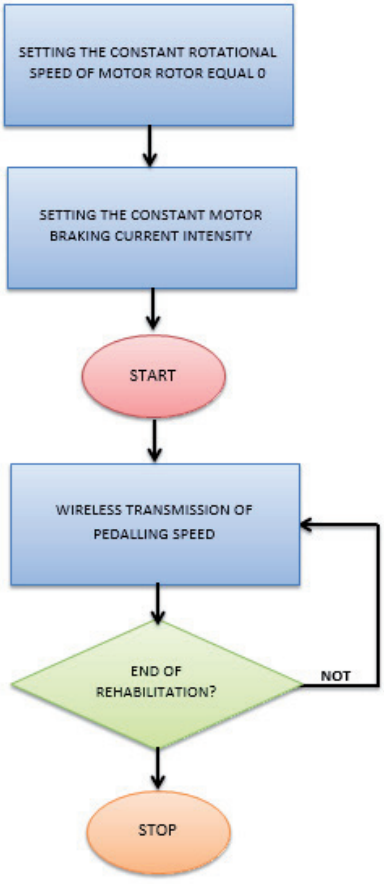

Fig. 5. Active rehabilitation control algorithm

3. Conclusions

The article presents a mechatronic interactive rehabilitation assisting system based on the stimulation of a child's senses with image and sound. The achievements of the modern multimedia content display technology have been employed for this purpose with an intelligent system controlling the rehabilitation intensity level and measuring a child's concentration. The solution proposed is a kind of modern physiotherapy combining traditional cyclotherapy with stimulation of a child's intellectual development by applying Glenn Doman's rehabilitation method or music therapy depending on a child's level of intellectual development. The muscles working while riding a bike are increasing their mass and strength. In the case of pareses or paralyses, the measures taken as part of therapy can restore the function of such muscles, by improving their flexibility, and increase their ability to react to stimuli from the nervous systems. The computer games created as part of the work are also enhancing a child's involvement in the physiotherapy process and stimulate brain development. It should be highlighted that a therapy conducted with the device proposed does not replace but only supplements the physiotherapy methods for children described in the work.

The considerations presented in the article obviously do not exhaust all the aspects associated with psychomotor physiotherapy of young children. The reflection presented here also indicates other issues which remain to be valid and underlie the future research. It may represent an assumption for tackling new aspects relating to, e.g. the use of robotised ortheses of lower limbs or to broaden the device's applications.

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