ANNALS

OF THE

UNIVERSITY OF CRAIOVA

Series: AUTOMATION, COMPUTERS,
ELECTRONICS and MECHATRONICS

Vol. 10 (37), No. 1, 2013

ISSN 1841-0626

EDITURA UNIVERSITARIA
Craiova, 2013

ANNALS OF THE UNIVERSITY OF CRAIOVA

Series: AUTOMATION, COMPUTERS, ELECTRONICS AND MECHATRONICS

Vol. 10 (37), No. 1, 2013 **ISSN 1841-0626**

Note: The **"Automation, Computers, Electronics and Mechatronics Series"** emerged from **"Electrical Engineering Series" (ISSN 1223-530X)** in 2004.

Address for correspondence:

Vladimir RĂSVAN
University of Craiova
Faculty of Automation, Computers and Electronics
Al.I. Cuza Street, No. 13
RO-200585, Craiova, Romania
Phone: +40-251-438198, Fax: +40-251-438198
Email: vrasvan@automation.ucv.ro

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New Approaches in Orthopedic Medical Education by E-Learning

E. T. Avramescu*, O. Lupescu, Gh. I. Popescu**, C. Patru**, M. Nagea****

** University of Craiova, Romania, Craiova, 13 A.I.Cuza Str. (e-mail: taina_mistico@yahoo.com)*
*** Clinical Emergency Hospital, Bucharest*

Abstract: The goal of the training programme for residency in orthopaedics in Romania is to produce orthopaedic surgeons who are technically competent and knowledgeable of the literature in the field of orthopaedic surgery. In addition, we hope to stimulate interest in solving clinical and basic science problems in the field of orthopaedic surgery. To accomplish this, the present paper offers solutions for improving resident training by using new approaches, such as an innovative e-training method that is able to provide the trainees with a range of case studies and an advanced training curriculum. These solutions are developed within the framework of a Leonardo da Vinci project Transfer of innovation, named “A Web-based E-Training Platform for Extended Human Motion Investigation in Orthopedics”. The project addresses to medical professionals, proposing formation of specialists that will systematically apply the principles of medical and bioengineering sciences in finding solutions that lead to improve health condition.

The main outcome of the project is a Virtual Training & Communication Center ORTHO-eMAN for innovative education - on-line education and training material accessed via a standard web browser, which provides an integrated on-line learning environment. The e-learning platform includes a repository of training material with real clinical case studies using digital imaging and accompanying notes, an interactive multimedia database system containing full reports on patients receiving orthopedic treatment. It will be used as a method of dynamic distribution of course information, but with innovative and more interactive uses. By following this programme we hope that the residents will develop patterns of life-long learning about the field of orthopaedic surgery, as well as an interest in making contributions to this field of knowledge.

Keywords: e-learning, orthopedics, medical education, case studies, human motion investigation.

1. BACKGROUND

E-learning, or the use of ICTs in support of teaching and learning, is often mentioned in the same breath as educational renewal and the construction of the knowledge society. Nowadays the value of e-learning in medical education, especially in LLL, is well recognised and there are a lot of approaches (http://ec.europa.eu/ education/leonardo-da-vinci/ transfer_en).

To meet better the health needs of the population, significant changes take place in medical education all over the world promoting the quality of higher education as essential priority. Integration of basic and clinical sciences, integration of theory and practice, implementation of problem-based learning, e-Learning and continuing all-life learning are important part of these changes, in unison of the recommendations of the World Health Organization, the World Federation for Medical Education, the European Commission (Directorate-General for Education and Culture), the national strategy for higher education and the strategy of the Medical Universities. Brown *et al.* (2007) identifies a transformative role for e-learning, with changes to views of learning and to the nature and operation of the tertiary institutions and the tertiary system.

A growing number of reports draw attention to the need of adjustment of the offer in medical education to labour market needs and the knowledge-based society. Increasing relevance and compatibility of bachelor university programs in relation to labour market needs and changes induced by the knowledge society by introducing e-learning in higher education institutions of medicine at multiregional level are some of priorities (Casebeer *et al.* (2010)). The main problem raised is represented by the reserved attitude of medical professionals regarding the use of e-learning and mainly using it for practical issues. Most of professionals believe that medical education is more suitable for theoretical concepts (guideline, procedures, protocols, legal frameworks, patient approach). Steps in infirming this concept were made in the last year by creation of virtual patients and simulations (Valcke and De Wever (2006)).

Recent reviews of e-learning literature in diverse medical education contexts reveal that e-learning is at least as good as, if not better than, traditional instructor-led methods (lectures) in contributing to demonstrated learning. Gibbons and Fairweather (1998) cite several studies, including two meta-analyses, which compared the utility of computer-based instruction to traditional teaching methods. Chumley-Jones *et al.* (2002) reviewed

76 studies on the utility of web-based learning from the medical, nursing, and dental literature, demonstrating evidence for more efficient learning via web-based instruction. Similar findings were reported by Schopf and Flytkjaer (2011) that described the benefits of online learning in the health sector and by Huckstadt and Hayes (2005) that mentioned online learning as a successful method in the education of advanced practice nurses.

The present paper presents a LDV/TOI project named "A Web-based E-Training Platform for Extended Human Motion Investigation in Orthopedics", coordinated by the University of Craiova, Romania. The project consortium is formed by higher education institutions (2 universities from Romania and Greece), 2 research centres (from Greece and Spain), an emergency hospital (from Romania).

The goal of our project is to encourage advanced orthopaedic care through achieving a greater understanding of musculo-skeletal conditions and treatments. Our aim is to develop new innovations in orthopaedic treatment, explore applications for new technologies, and enhance the results of surgical procedures. We also impact surgical outcomes through the design, assessment, and evaluation of knowledge and therapies.

2. METHODOLOGY

The main result of our project is a Virtual Training & Communication Centre ORTHO-eMAN for innovative education - on-line education and training material, accessed via a standard web browser, which provides an integrated on-line learning environment. It will be used as a method of dynamic distribution of course information, but with innovative and more interactive uses, by including a lifelong learning platform consisting of three main components: (a) E-Learning, (b) E-Communicating and (c) E-Mentoring. The platform provides a repository of training material with real clinical case studies using digital imaging and accompanying notes, an interactive multimedia database system containing full reports on patients receiving orthopaedic treatment. The learners have control over content, learning sequence, pace of learning, time, and often media, allowing them to tailor their experiences and to meet their personal learning objectives. Interactivity allows trainees to test their knowledge and provides immediate feedback using images and cases that they could encounter in clinical practice. We developed an innovative e-training method that is able to provide the trainers with a range of case studies.

The target groups that will be reached during the life of the project, are:

- In terms of persons: medical, physiotherapy and bioengineering trainees in different types of vocational training, specialists in orthopaedic practice (CME by postgraduate courses), physiotherapists and biomedical engineers involved in implants development and manufacturing and movement analysis, employees and managers in medical institutions, research entities, orthopaedic device manufacturers and marketing, educational staff in heath compartment;
- In terms of organizations (target sectors): universities, public and private medical institutions, manufacturing, import and distribution companies and associations of healthcare technologies, stakeholders, EU structures in the field (education and health).

In this way the project benefits three different communities of users: Universities and University Associations, Enterprises and Enterprise Associations and trainees and their associations.

The target groups will be reached by intensive dissemination by various modalities and by using the partner's professional networking.

Foreseen benefits (impact) for the target group are:

- *increased level of knowledge and skills* of the trainees by new training content and curriculum elaborated by professional educational institutions with regard to the existing needs;
- *increased flexibility, attractiveness and accessibility of training* by providing easy usable teaching and a learning tool suitable for lifelong learning;
- *offering equal chances to knowledge* by developing an e-learning platform accessible for professionals in different locations and from different partner countries;
- a higher degree of *efficiency* in terms of easy access and the ability to put into practice by physicians of newly available information. Due to increased level of interactivity owned by "e learning" (online courses, etc.) professional development via the Internet proved, compared to traditional methods of education;
- *economic impact*, lowering the costs of training (travel/accommodation in university centres);
- *increasing virtual and real mobility and improvement of language skills* by the use of a multilingual e-learning platform;
- *improvement of VET systems* in bioengineering and orthopaedic sector in partner countries; especially in Romania a few degree programs use e-learning programs and emphasize applications in medicine and health care. There is a paucity in online learning opportunities, it is quite novel and not widely spread in Romania, it would make education and information more accessible without the need to travel to certain institutes, and it could also be used anytime, not only on the rare training courses once or twice a year, not to mention it would be free which is also a considerable fact;
- *harmonisation in higher education* for training curricula, learning methods, communication systems and specific language, *as first steps in the development of an Educational Network in Orthopaedic Medicine*;

Main methodological / didactic approaches:

- defining the target groups in terms of structure and number, identifying and analysing user demands and e-learning needs for LLL and EBM;
- defining on adaptation of e-learning platform (feasibility of transfer and methodology in transfer of results);
- defining a new platform development (technical and didactic teams, teaching level, specific content of each module, multimedia approaches as text, graphics, animation, audio, video, etc, evaluation system of the trainees);
- defining the alternative applications of on line learning (new approaches/adaptations, virtual classrooms; measuring added benefits);
- elaboration of the new e-learning platform and training modules; integration of modules within the platform (training packages);
- on line training; assessment; certification;
- integration in national and/or sectoral training systems as part of the resident training or/and continuous training.

The partnership's medical practitioners revised existing materials and created new training modules (best practice) delivered via the internet. The technical teams took care of adaptation of the platform and integration of training materials. Tutoring for trainers and trainees is foreseen.

The platform and training materials were first developed as working versions/prototypes. Pilot testing of the prototype by the users took place by selecting a test group from the target group that we address to. The test group evaluated if the prototype respond to the user's needs and correspond to quality requirements (level of knowledge, user interface, language level, graphical approach, level of interaction) by questionnaires. Feedback from the users was gathered by a trialling team with the use of a Trial Checklist in order to assess the materials against quality criteria and to identify potential changes that will be incorporated into subsequent forms. Evaluation of products effectiveness and impact (expectations and customer satisfaction questionnaire for the target group) and evaluation of project usability and transferability by questionnaires addresses to end users, stakeholders and open public are foreseen, as well as creation of a Focus Group.

Technologies from another project that has been running separately in recent years were used in an integrated way. The previous project entitled "e-MedI – Virtual Medical School* had as main result a web-based training environment, utilizing a multimodal breast imaging paradigm. The e-MedI architecture was based on a client-server 3-tier architecture that consists of the following core elements:

A. Learning Management System (LMS);

B. Visual Authoring Tool;

C. Trainee's interactive e-training environment;

D. Keyword-guided Clinical Case search tool.

After analysing the feasibility of transfer we decided that the e-MedI platform can be modified and adapted to our objective, an extended human motion investigation for orthopaedics (ORTHO-eMAN), as shown in Figure 1. The LMS is by definition a complex administrative system used to deliver electronic content in the form of lessons and to organize people who attend these lessons and the LMS core can be used in the same form for ORTHO-eMAN. These requirements led the ORTHO-eMAN project to the decision to implement the Authoring Tool as a plug-in of the LMS. The chosen LMS was Moodle and the development effort was led to the ORTHO-eMAN plug-in.

The plugin consists of 3 parts:

- plugin-core: handles the integration with the Moodle (authentication, data. grading), written in PHP;
- Authoring Tool: handles creation and editing of the content. It is a GWT application meaning that it compiles to JavaScript and runs the client side in the user's browser. It calls out the plug-in-core for services regarding Moodle integration;
- Display Tool: handles the presentation of the content to the trainees. It calls out to plugin-core for services regarding Moodle integration.

The presentation tier is adapted to include additional data provided by specific modern investigation methods of ORTHO-eMAN, including medical imaging, video files of motion analysis, force graphs, muscle and joint reactions, numerical data, contact pressure diagrams, etc.

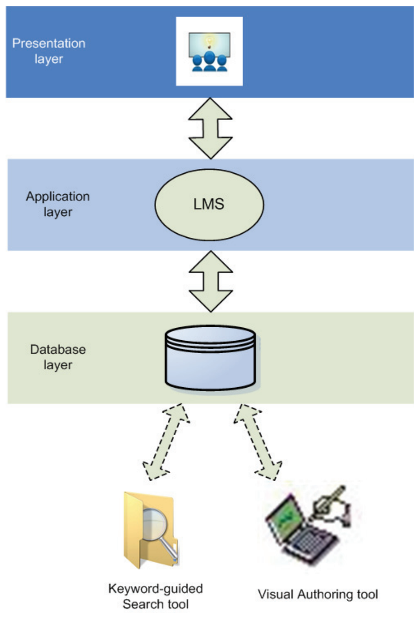

Fig. 1. Client-server 3-tier architecture used in the development of ORTHO-eMAN platform.

Some added values of this project are:

- Development of interactive training modules by using out-line courses presentations and on-line courses on theoretical issues, case studies (patient medical background, clinical signs, paraclinical evaluations, X-Rays and MRIs, clinical tests and valid biomechanical tests- clinical gait analysis). Each case study indicates the correct diagnosis for trainees (interactive feedback).

- Using of an Authoring Tool that creates case studies consisting of patient's general information and a set of consecutive stages Each Stage is a data point in patient's diagnostic time line. And is associated with one or more visual content objects (i.e. 2D, 3D images and video sequence), which are the acquisition outputs of one of the available modalities (MRI, Tomography, video processing, pressure pattern). The theoretical studies include the most important information regarding the anatomical and biomechanical aspects of human motion; the case studies were chosen due to the fact that there is a complete gap within orthopaedic training nowadays, concerning imagistic diagnosis. Although the residents are theoretically taught the specific elements of skeletal pathology, very little is done for testing their ability to evaluate the outcome of orthopaedic treatment. That is why the cases are presented with their Xrays/ CTs/MRIs and motion analysis so as the trainee should identify the most important imagistic findings, correlate them with motion analysis and establish a proper treatment

The Authoring Tool creates a XML description of the whole course and it is used by the Display Tool to reconstruct the course and present it to the trainees. The XML document is stored along with the other resources in the Moodle database. Regarding its main features, the Authoring Tool itself is capable of creating multimedia content by letting the users upload images and video. The teacher can then create quizzes of the following type:

- Find Region Of Interest (ROI). Multiple ROI may be requested by the teacher. This is important for the trainees because it improves their ability to evaluate an image as a whole and find the pathologic findings. For example, the trainee is asked to indicate the mechanical problems within a certain type of osteosynthesis, which requires a proper understanding of the biomechanics of the initial injury and knowledge regarding the correct treatment , otherwise the trainee will not be able to identify the pitfalls. Having that performed will definitely generate two effects: first of all , a " don't do like that" alarm sign which will be activated when the resident will have to treat a similar injury by himself; secondly, the trainee must establish a correct treatment in a very real situation, in a defined amount of time , as in daily medical practice. (Fig. 2)

- Quiz: Multiple answer quiz. (None, one, or more answers can be correct). The questions will be similar to those that the practitioner has to answer to when treating the patient, so they have a very clear practical character; although theoretical knowledge is strongly needed, the trainee will not be able to answer the quiz unless they integrate theory and apply it to each particular case, as it happens in reality in orthopaedics. This very strong character of reality-reflecting gives value to our system since little has been done until now for "simulating" orthopaedic patients and apply the principle of interactivity in orthopaedic training.

Fig. 2. Identifying the regions with pathologic elements.

- Range Quiz: A question that has a number for an answer. The teacher specifies the minimum and maximum allowed value for the answer to be considered as correct.

The Authoring Tool also has some standard image processing tools such as brightness, contrast, inverse that are heavily used in X-Ray setups. Angle calculation and cross-hair tool were added specifically for the ORTHO-eMAN project.

Angle calculation was considered of particular interest since treatment of deformities in skeletal pathology starts with their angular evaluation which also rules their treatment; different angles mean different treatment, so this e-learning tool gives the trainee the possibility to evaluate his ability of finding and calculating the angles unanimously accepted as significant (Fig. 3).

In the following picture (Fig. 4) the Authoring Tool is depicted as part of a Moodle installation.

The Display Tool supports several tools that were not available in the previous Flash implementation

- back and forward functionality
- tracking (trainees' progress)

The display tool is implemented in HTML5 language and analytically, it adheres to the user interface skeuomorphism design guidelines and principles. Therefore, the display tool emulates for each lesson the function of the book. Moreover, each page corresponds to each containing lesson case (Fig. 5).

Fig. 3. Calculating the angles.

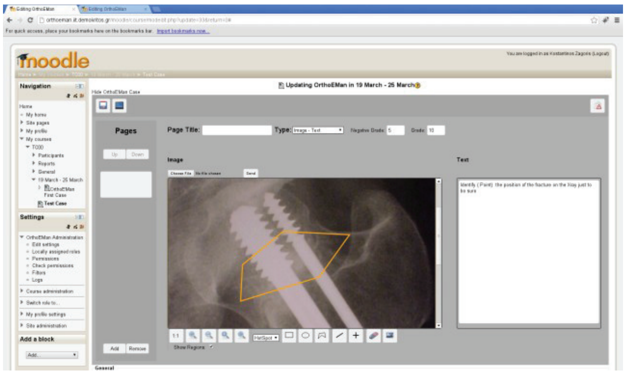

Fig. 4. Authoring Tool fully integrated to Moodle LMS: ROI - Image – Text.

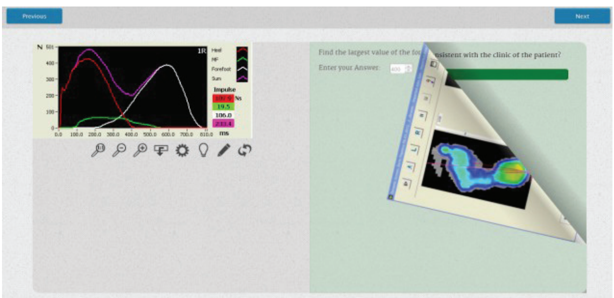

Fig. 5. Display Tool.

The original scientific issue of this approach consits mainly in the fact that the broad-based educational tool was developed using evidence-based medicine and new biomechanical technologies related to real-life scenarios that are relevant for the user groups - residents and specialists in orthopaedic practice. In this way the e-learning platform developed by us does not deal only with a technological problem for trainers in defining a medical case study but aimes to develop strong conceptual skills, helping the trainee to think creatively and solve problems.

3. RESULTS

Medical doctors will follow pressure plate case studies in relation to orthopaedic case studies. By using the integrated learning environment and making use of a fair number of real case studies, the medical trainees will be able to identify, classify, diagnose and propose the appropriate action or treatment, identify the risk zones, appreciate the efficiency of the treatment or rehabilitation programme.

The e-training environment is multilingual (English, Greek, Romanian and Spanish languages), as shown in Fig. 6.

Fig. 6. The structure of the Human Motion Analysis Course.

The case studies include measurements recorded for persons without known orthopaedic pathology and measurements recorded for persons with gait abnormalities. Measurements refer to clinical tests and clinical gait analysis and are analysed before and after surgery and/or rehabilitation. The trainees must use the system specifications that allow comparison of measurements. In Fig. 7 is shown the start of a case study and in Fig. 8 an example of case study development.

The Authoring Tool provides simple tools to draw region of interest like rectangles ellipses and polygons to mark the region of interest. Our implemented features within the interactive e-learning platform for pressure plate (Footscan) measurements allow the trainee to:

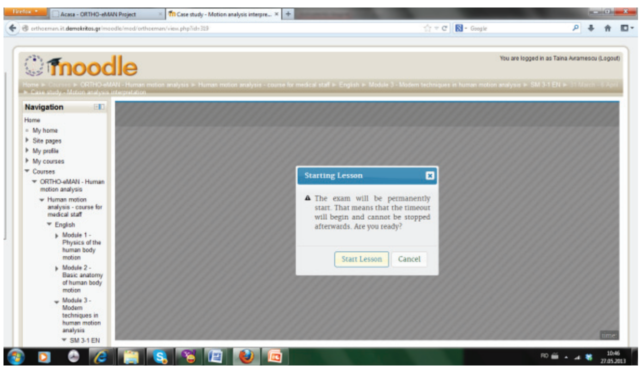

Fig. 7. Starting lesson - case study.

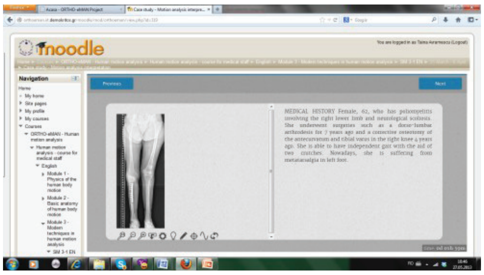

Fig. 8. An example of case study development – clinical analysis.

- select a point in the image by mouse click or designate an area also by employing the mouse. This will be used for example to indicate zones of abnormal high or low pressures, identify the centre of pressure, the highest impulse area, the contact percentage, foot axis or foot angles;
- measure angles;
- draw a horizontal and a vertical line on the graph image; both lines form a crosshair-like object that will allow to target any desired point on the graph and estimate it's values for x and y axes;
- in some cases, text boxes provide the trainee a way of inputting measured or estimated graph values.

Some cases include images in motion, which are actual recordings of pressures exerted on patient's feet during roll-off. The e-training platform offers basic movie player controls such as Play/Pause/Stop functionalities and Rewind. It also provides a way to play the video material regarding the movement for both feet. The trainee will have to watch the video (the evolution in time of the stepping process) and answer a quiz regarding abnormal features of the movement.

4. CONCLUSIONS

Our course in Human Motion Analysis is developed in order to help the trainee to understand and solve case studies regarding data acquisition and analysis of human motion using specific devices and software as pressure plate and video motion analysis by Simi Motion. The broad-based educational tool was developed using evidence-based medicine and new biomechanical technologies related to real-life scenarios that are relevant for the user groups - residents and specialists in orthopedic practice.

The developed e-training platform was designed to support e-learning, to manage access to e-learning materials, consensus on technical standardization, methods for peer review of these resources. Our solution presents numerous research opportunities for the target group, along with continuing challenges for professional development and it combines the design and problem solving skills of engineering with medical sciences, improving healthcare diagnosis, monitoring and therapy.

The proposed e-learning methodology for achieving these tasks is a viable alternative, as it motivates the development of a number of on-line learning/training environments.

Achievement of these aspects allows a close cooperation, by working in a team, between doctors and biomedical engineers for diagnostic and treatment targeting.

The integration of e-learning into graduate and continuing medical education will promote a shift toward adult learning in medical education. Integrating the results into national systems - mainstreaming of project results into education systems is previewed as the best solution to guarantee that the project has a long-term impact. Decision-makers will be regularly addressed by a coherent advocacy strategy and the project outcomes will be developed in order to be easily adapted for use in other contexts. The project would be supported and continued by the recognition of training courses and certification on national level for all participant countries as mentioned in WP6. We foresee the following ways:

- Medical education: residents - this e-learning platform could be part of the practical, where we could introduce surgical videos with explanations during class, the description of surgical techniques/ rehabilitation protocols could be considered extracurricular activities for extra credits.
- Postgraduate: Trainees in orthopaedics have certain mandatory courses they must attend, and there is one called "Surgical Techniques", and one called "Rehabilitation", both are 1 week long courses, the e-learning platform could be added to the teaching material, or alternatively, it could serve as an extra help for the trainees to be able to complete these courses.
- Orthopaedic surgeons: they must revalidate their license in every five years, and in order to do that, they must attend courses/congresses/give lectures etc. to get the required amount of credit. The e-learning platform could be accredited by university, and serve as an online teaching tool, and allow surgeons to learn/get extra credits whenever it suits them.

ACKNOWLEDGMENT

This work is supported by LLP-LdV-ToI-2011-RO-008 grant. ORTHO-eMAN ("A Web-based E-Training Platform for Extended Human Motion Investigation in Orthopedics") is a two year European funded project 2011-1-RO1-LEO05-15321 (Contract LLP-LdV/ToI/ 2011/RO/008). The project has been funded with support from the European Commission. This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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Modelling of the Upper Limb Wearable Exercisers

Beniamin Chetran*, Simona Noveanu,**
Gelu Răducanu*, Olimpiu Tătar****,**
Dan Mândru***

Department of Mechatronics and Machine Dynamics,
Faculty of Mechanical Engineering, Tehnical University of Cluj-Napoca, Romania
** e-mail: Beniamin.Chetran@mdm.utcluj.ro*
*** e-mail: Simona.Noveanu@mdm.utcluj.ro*
***** e-mail: Olimpiu.Tatar@mdm.utcluj.ro*
****** e-mail: Dan.Mandru@mdm.utcluj.ro*

Abstract: Robot-assisted rehabilitation procedures have clear advantages, already recognized. The researches in this field often involve the development of models of the upper limb and robotic system. In this paper, some models of portable exoskeleton-type rehabilitation robotic systems are emphasized and an original MATLAB model of upper limb – wearable exerciser ensemble, is given. The results of simulations for different combination of anatomical movements are presented and used for actuators selection.

Keywords: Physical therapy, rehabilitation, exerciser, modeling, exoskeleton, upper limb

1. INTRODUCTION

The wearable rehabilitation robotic exoskeletons become useful tools for more efficient rehabilitation processes, being able to repeat with the patients large range movements which would otherwise be done by the therapists. Moreover, a useful feedback to the therapists is provided, based on precise recording of forces and movements. It has shown that this type of robot-assisted rehabilitation therapy allows objective assessment for recovery process, improves morale and motivation, promotes home exercises and training, Rui et al. (2011).

Usually, the wearable rehabilitation robotic exoskeletons have a serial architecture in accordance with upper limb kinematics. Much research in this field refers most often to the modelling of the robotic systems, useful in the design of their mechanical structure, actuation and control systems. The kinematics of the 5 DOF exoskeleton rehabilitation robot for upper limb described in Qinling et al. (2009), is analyzed with a model based on Denavit-Hartenberg (D-H) method, in order to conceive a two-stage (passive and active-resistant) rehabilitation procedure. The same D-H method was applied in Wu et al. (2011) for the kinematic model of upper limb – elbow exoskeleton ensemble. In addition, an analytical model of joint torques was developed for design of the elastic elements which provide necessary resistance for shoulder and elbow movements. A 2 DOF wrist exerciser has been kinematically modelled using modified D-H notations, Rahman et al. (2010). A dynamic simulation is also proposed, with a nonlinear sliding mode control technique. D-H method is used for the positional analysis of a 4 DOF shoulder and elbow exoskeleton, while the Lagrange-Euler method is used for its dynamic analysis; the human arm and rehabilitation robot were modelled in MATLAB SimMechanics, Parasuraman et al. (2009). Specific model is proposed in Mustafa et al. (2005) for the 3 DOF shoulder module of biologically-inspired anthropocentric exerciser which consists of cable-driven parallel mechanisms.

Browsing the references it results that the wearable robotic exoskeletons for functional compensation provide the required mechanical power being controlled through the signals provided by the users. For active-resistant exercises, the exoskeletons have more complex functions and different control methods, as well as those for interactive exercises, which react to user's command to provide the desired assistance. A précis control of velocity and torque is given by the actuation systems based on DC motors. Besides these, other actuators were implemented in wearable robotic exoskeletons: pneumatic actuators, McKibben artificial muscles, electroactive polymers, etc., considering a balance between power and weight.

2. THE PROPOSED MATLAB MODEL

In our previous works, a 7 DOF kinematic model of upper limb was developed, Mandru et al. (2012) for which have been obtained the equations for both forward and inverse kinematics. Also, a model for a wearable exoskeleton robotic exerciser with 3 DOF (shoulder, elbow and wrist flexion-extension) was developed. It gives the opportunity to deduce the forward and inverse kinematics equations for above-mentioned exerciser.

The aim of the proposed MATLAB model is to obtain useful information about kinematic and dynamic parameters specific to a robotic exoskeleton exerciser attached to the upper limb, during different movements, in order to establish the final design of the exerciser, including its actuators, links, brakes, clutches and control system. At the beginning the upper limb model was developed by using an imported 3D CAD mannequin (Fig. 1), The MATLAB reference coordinate system was attached to the trunk. For each segment of the upper limb, the characteristics like length, centre of gravity and so on