E-LEARNING SYSTEM FOR MEDICAL EDUCATION BASED ON THE GEOMETRICAL MODELS OF HUMAN BONES AND FIXATORS

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Abstract: *E-learning systems in the form of virtual learning environments (VLEs) are important part of medical education. Virtual Simulators (VSs) can be considered as components of VLEs and they can be applied in training of medical students, practitioners and surgeons. VSs include the use of Virtual Patients (VPs) which can be in a form of 2D/3D geometrical models, Electronic Health Record (EHR), electronic case-studies, etc. In this paper authors present new VLE which is a part of web oriented Content Management System (CMS), and it is based on VS which uses geometrical models of human bones and fixators. The VLE consists of two connected learning modules. The First module of the system contains a set of educational videos which show implementation of fixators and bones models in virtual orthopedic interventions. The second module contains a web based graphical application which enables assessment and implementation of knowledge gained through the first module. The aim of presented VLE is to provide medical students and orthopedic surgeons with a better understanding of orthopedic interventions, and as a consequence, to improve their quality.*

Keywords: *E-Learning, Distance learning*

1. INTRODUCTION

E-learning has become an essential element of training for medical professionals, practitioners and students of medicine. Modern information and communication technologies implemented in the e-learning provide access to a large variety of resources and information which can be: scientific papers, videos, books, VoIP, etc. In order to facilitate access to different types of information and resources, it is necessary to create integrated information systems such as Virtual Learning Environments (VLEs). Such systems have become the basis for training in today's medical education [1, 2]. What these systems need to provide, and what defines the difference between e-learning systems and traditional multimedia training [3], is: accessibility to fresh information, ability to easily change content, and potential for constant improvement. In general, the medical training of surgeons and students can be done by the use of:

- Patients
- Cadavers
- Animal models
- Synthetic models
- Computer-Assisted Training (CAT)– specially developed software tools for the simulation of certain activities

Learning technical skills by performing surgical interventions on real patients can raise ethical issues. In hospitals where training is performed, it is not surprising that surgeons conduct surgical interventions while they are under some degree of control by experienced surgeons. Although the use of cadaveric material has its positive side, there are problems that need to be considered, such as: this material cannot be reused; chemical solution for fixation is necessary, etc. Problems that arise with the use of animal models are of ethical and anatomical nature. The use of live animal models for surgical practice has been forbidden in the UK, unlike the U.S. and Europe.

CAT provides many benefits to medical education compared to classical training. It reduces training costs and allows users (surgeons, students) to work with virtual bones models in virtual environments [4] as presented in Figure 1. Orthopedic surgery is a discipline that demands good understanding of the complex 3D structure of bones and their relationship with the nerves, blood vessels and other vital structures. Learning these skills takes time and lots of practice. CAT can reduce time required for learning, as well as save cost and equipment [4].

CAT helps surgeons to plan complex procedures for a particular patient. Surgical simulators create a virtual environment where surgeons can simulate and plan operations. These virtual environments are often realized with: realistic look of operating rooms, parts of the human body reconstructed from CT or MRI data, surgical instruments and implants, realistic sounds embedded in a scene, etc.

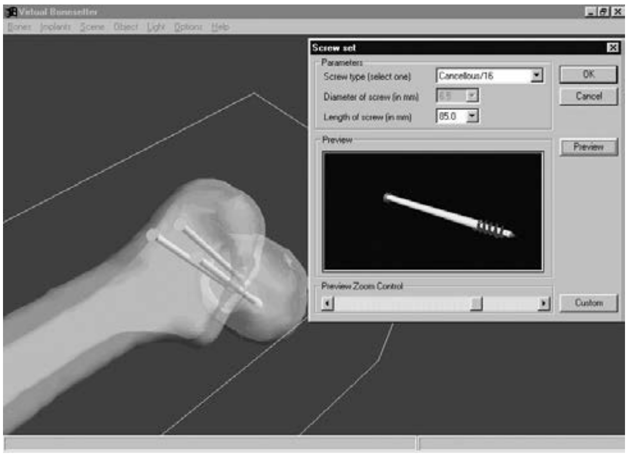


Figure 1. Virtual femoral neck fracture fixation with cancellous screws [4]**.**

There is a significant difference between the Computer-Assisted Surgery (CAS) and CAT. CAS assists and guides the surgeon during real surgery, and CAT simulates only certain aspects of these operations with a satisfactory dose of reality [4]. CAT in the field of orthopedic surgery and general orthopedics is very complex and the use of VLE and Personal Learning Environment (PLE) can contribute to a significant improvement of students' and surgeons' knowledge and practical education. PLE can allow a certain freedom in controlling and creating content, and in defining the process and ways of learning, which can be very useful in medical education [5].

The CAT and simulations (animation) of surgical interventions are very important element in surgical education. In order to enable surgical simulators implemented in CAT, virtual geometrical models of human bones and implants (fixators) need to be created. For the creation of geometrical models of human long bones, Method of Anatomical Features (MAF) can be used. The MAF method is described in detail in [6, 7]. Models created by MAF can be used in a software packages for training orthopedic surgeons and students. Other types of methods for the creation of human bones geometrical and other types of models are presented in [8, 9]. The new approach for the creation of geometry and topology of fixators by Mitkovic which correspond to the geometry and topology of the bone of the patient is presented in [10]. The geometrical models of fixators created in this way enable a better preparation and execution of surgery and hence the recovery process of the patient.

In this paper authors present new VLE which is a part of Content Management System (CMS), and it is based on Virtual Simulator (VS) which uses geometrical models of human bones and fixators. The VLE consists of two connected learning modules. The First module of the system contains a set of educational videos which show implementation of fixators and bones models in virtual orthopedic interventions. The second module contains a web based graphical application which enables assessment and implementation of knowledge gained through the first module. The aim of presented VLE is to provide medical students and orthopedic surgeons with a better understanding of orthopedic interventions, and as a consequence, to improve their quality.

2. THE STRUCTURE OF THE SYSTEM

Web site (http://vihos.masfak.ni.ac.rs) created by the use of joomla Open Source CMS is the basis of the system. This system provides complete control over content and system users, which is vital regarding security and system upgrades. The home page of the web application is presented in Figure 2.

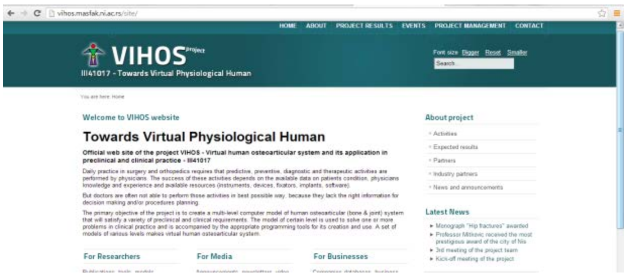


Figure 2. Web site home page

The basic scheme of the system is presented in Figure 3. The CMS uses two servers, one of which is the web server, and the other is database server. Both servers are on one computer which is protected by the firewall. VLE is defined as an integral component of the system that has access to all the resources of CMS. Users of the system can access virtual content of the VS (and VLE) through the web browser. Access is enabled through the links (articles) placed within the CMS system.

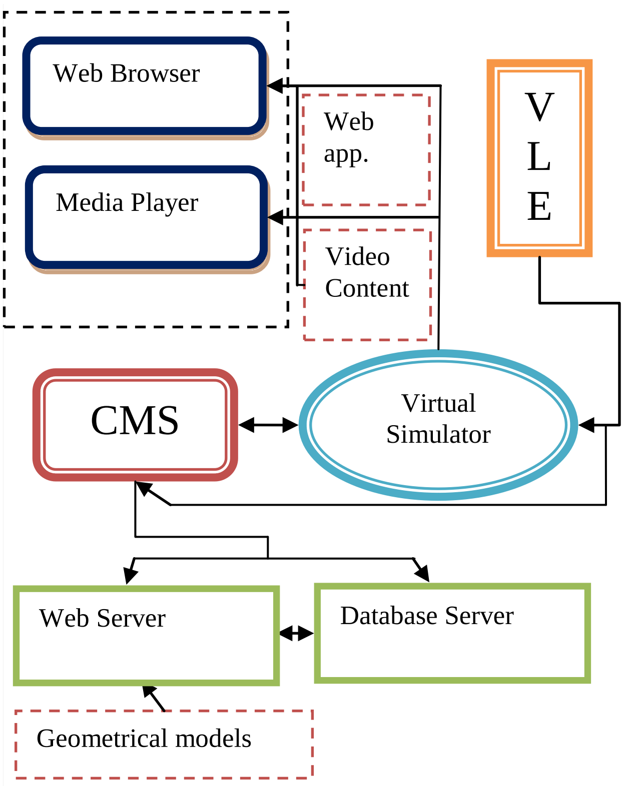


Figure 3. The basic scheme of the components of the system

Users have the ability to view video tutorials (first module) in a web browser, or to download them and watch offline. Higher level users (administrators, teachers) have the right to publish video tutorials, as well as to delete them, or to restrict access to a specific group of users. Video tutorials are divided into two groups: the videos which are free to view, and the videos that are protected by access rights. Videos which are under protected contents usually contain some information which cannot be displayed to regular users of the system like: patent related data, some innovative design, etc.

The second module includes a web oriented graphical application that is intended for simulation of orthopedic surgery. The application was created as Web3D application, which involves the use of web technologies aimed at displaying 3D content. Users of the system can implement and test knowledge gained through video tutorials in a web application. Web application is based on the use of geometric models of fixators and bones placed in a separate folder on the web server. The access to these models is not limited to the web application only, yet some groups of users with adequate rights (designers, teachers, and administrators) can access them directly through FTP connection.

3. DESCRIPTION OF GEOMETRICAL MODELS

Geometrical models of bones used in VS are created by the use of Method of Anatomical Features (MAF), described in detail in [6, 7]. The MAF contains three preparatory processes which must be performed in order to generate valid geometrical models (surface, solid, parametric model) of the specific human bone, and they are:

- Creation of Anatomical models of human bones (P1)
- Creation of Referential Geometrical Entities (RGE) (P2)
- Creation of Skeleton model (P3)

The applied method for creating the human bone geometrical model is based on anatomical properties (anatomical model) and human bone morphology.

Anatomical bone model is, in its essence, a semantic (descriptive) model in which anatomical definitions are taken from medical sciences, and it defines terms referring to certain areas on geometrical bone model. In other words, the anatomical model can be described as a set of anatomical landmarks which are defined on each bone and well known in medicine.

In connection with that, the first step is semantic defining of anatomical areas on human bone, i.e. creation of anatomical bone model, as well as informing about basic bone morphology (P1).

After creating the anatomical model, creating of the basic model geometry is introduced. Initial preparatory processes are: Computer Tomography (CT) scanning part of the human body or dry samples; Preprocessing of raw data (scans) and its transformation into STL format; Importing the scanned model in STL format into CAD application (for example CATIA) and its further preprocessing; Cleaning the cloud of points; Tessellation and Healing the tessellated model. At the end of the preparatory processing processes, polygonal geometrical bone model is created. The upper stated processes are so called preparatory processes for a very important procedure of referential geometry defining - RGEs (plains, lines, axis, points, and so) [6] which is defined on polygonal human bone model in accordance with its anatomical and morphological features. After defining RGEs (P2), the examination of polygonal bone model follows, in order to create geometrical entities which will serve as base for creating the geometric model(s). Geometrical entities are mainly spline curves (B-spline) and are defined to follow bone geometry and topology the best way possible and all in accordance with anatomical bone model (P3).

These entities serve as the basis for the creation of adequate geometrical models. They can be used for the creation of:

- Geometrical points for the parametric bone model [5, 6]
- Polygonal, Surface and Volume models [8, 9]
- Finite Element Models,
- Geometrical models of bones missing parts, etc.

The process of creation of fixators geometrical models are presented in [10]. In that paper the whole procedure for the creation of customized geometrical models of human fixator by Mitkovic is presented. The main benefit of applied procedure is that geometry and topology of fixator is customized to fit the patient bone in best possible way.

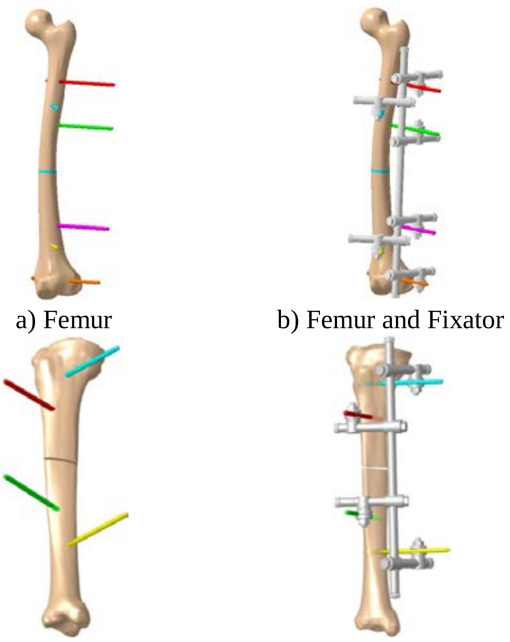
One of the reasons why MAF method and procedure for the creation of customized fixators are developed is to help orthopedists and students to better comprehend the anatomy, geometry and topology of human bones, and to use that knowledge in better preparation of orthopedic interventions.

4. VIDEO TUTORIALS MODULE

The models of human bones created by the MAF method and fixators models were used for the creation of simulation (animation) in CATIA which is one of the leading software packages for CAD/CAM/CAE. Eminent orthopedic surgeons were consulted in order to create a proper simulation of orthopedic surgery. Adequate simulations/animations were created on the basis of the instructions obtained from them. Surgeons and students can learn proper positioning of fixator to the bone, order of elements setup (e.g. screws), how to orient fixator to the bone, and more.

The created video tutorials are converted into a format appropriate for posting on a web server. It was highly important to maintain adequate video quality, while not making them too large to download from web server, or watch online. In addition to web server posting, files are also posted on YouTube, to enable easier access to users. This way, video tutorials are available to general medical and other community (this only applies to publicly available tutorials).

Figure 4 shows the individual frames of video tutorials which presents bone and bone-fixator assembly.



a) Femur b) Femur and Fixator

c) Tibia d) Tibia and Fixator

Figure 4: Individual frames of bone and bone-fixator assembly

5. WEB APPLICATION MODULE

Polygonal bone and fixator models are used in a web application for the preoperative simulation in orthopedics. The application is based on the use of 3DContent and HTML5 technologies, implemented through X3Doom. X3Doom is open source framework which allows definition of: vertices, triangles, lights, normals, etc. which completely defines the corresponding 3D model and the scene where the object model exists.

The application does not need any additional software besides modern web browser. It allows the transformation of basic models (rotation, translation, scaling), and pairing bone and fixator models in the appropriate assembly, as presented in Figure 5.

The image of the current scene can be captured. Users of the system can send image(s) to the tutor who can check if everything was done properly, or if there is a problem to help solve it.

More information about web application can be found in [6]. Based on information obtained in video tutorials, system users can, individually or in groups, with or without supervision, apply the acquired knowledge in this application. This way, they can test whether they understood the instructions, and whether they can achieve the same result as the one presented in video materials.

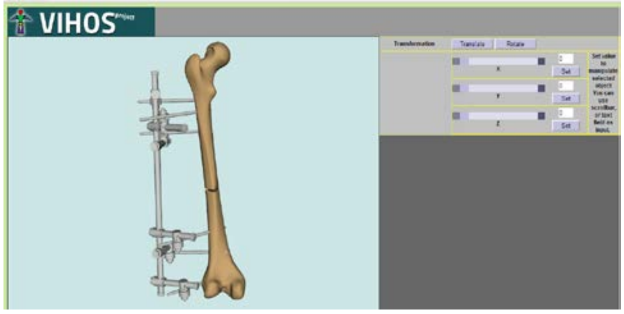


Figure 5: Interface of Web Application

6. CONCLUSION

Video tutorials and web application presented in this paper allow users of the VLE system to analyze their content alone (e-learning), or with the help of tutors (e-teaching) and to apply and test their knowledge. Further work on the VS involves several directions. Creating a larger number of bone and fixator models will allow more video tutorials, which will extend and improve knowledge database. Also, including models of other human body parts (such as muscles and tendons), as well as additional medical equipment (equipment used in surgery), will allow the creation of material that contains enough information to simulate the whole surgery, not just the pairing of fixation and bone.

VLE system provides basic ability to work in groups. The full implementation of Problem Based Learning (PBL) will enable users to establish an organized system of communication which will raise the system's functionality to a higher level. PBL requires a well-designed e-learning system, which must comply with certain procedures, such as: the possibility of a well-defined clinical case, ownership of the training material, defined user groups, implemented forums and chat rooms, etc. [1]. VLE presented in this paper does not contain all the elements needed for the full implementation of PBL, but it is possible to implement it trough further improvement of the system.

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