

A Virtual Reality Based Simulator for Gynecologic Exam Training

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Abstract—Training is an effective way to acquire knowledge. In the last years, realistic training has been proposed and offered by the use of virtual reality (VR) systems. This work presents a VR based simulator for gynecologic exam training - the SITEG. This system integrates stereoscopic view and touch to simulate a real exam in a virtual environment. In this environment the user can practice and learn different gynecological pathologies in several stages.

Index Terms— Haptics, Medical Education, Realistic Simulation, Virtual Reality.

I. INTRODUCTION

EDUCATION is a relevant factor in the development of a society. Virtual Reality (VR) technology is indicated as one of the main areas that can offer significant results for the learning process. One of its potentialities is the possibility that students have to visit and to interact in virtual environments where factors as safety and time will not affect a third part. These features contribute to students' knowledge construction [1].

In the medical area, some applications for learning based on VR have being developed. Such applications offer several advantages over the traditional methods of education, training and assistance by the immersion of the student in the problem subject [2].

The traditional training of gynecological exam consists on theoretical classes followed by practical experience during medical residence. Once this exam is composed by a visual and by a palpation phase, there are several problems in this way of training. Pictures and images can help to teach the visual phase, but the palpation phase depends on the experimentation. Besides that, there are different stages for a

same pathology and some of them are very rare and are not frequently observed in hospitals. In this context, it is observed that cervix cancer is one of the most common malignancies among women. Its occurrence is only exceeded by skin cancer and breast cancer. For the year of 2003, the estimates pointed the occurrence of a hundred and thirty six thousand new cases in a worldwide scenario [3].

This work is related to the development of a VR based system for medical training of gynecological exams, the SITEG. The goal of the system is to offer a tool for training the identification of malignancies related to cervix cancer in female patients. In this VR environment the user can perform both phases of a gynecological exam and learn how to identify pathologies and their stages.

II. VIRTUAL REALITY TECHNOLOGY

VR is a recent technology that combine computers, physics, graphics, electronics, cognition and many other concepts. A VR system is a real-time application which goal is to produce realistic applications to explore human senses [4]. The senses more explored are the vision, audition and touch, but recently have been developed technology to explore the smell and taste senses [5].

The realism of a VR system is related to its capability to provide immersion and interaction for the user. The immersion should involve the user in the subject of the application and the interaction should provide friendly and natural ways of communication between the user and the computer. For that, several devices were developed in last years. The visualization can be enhanced by stereoscopy with the use of head-mounted displays, special glasses [2] or auto-stereoscopic displays [6]. Motion-capture devices, joysticks, wands, gloves and biological input devices can capture user movements [4]. The use of other devices for interaction in three-dimensional spaces as trackballs and robotic arms [7] also affect the realism of a VR application. Sound displays allow to positioning the sound in space and help identify objects and people distance in the virtual world. Figure 1 shows examples of specific devices used for VR system developers.

Besides devices, the VR technology also combines algorithms to treat visualization and interaction tasks. These algorithms must guarantee the real-time of the application, avoiding delays to process responses from an interaction. So, when the user touches an object in the virtual world the system must provide the correct visual answer as a deformation of the

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object, as example. It means that the collision with the object must be detected; the correct point of contact determined and the new position of the point need to be calculated according the direction of the touch. All must be processed and presented in real-time. As many senses the VR system explores, as many detailed the objects are, more complex is the processing [4].



Fig. 1. Devices used to explore senses in VR systems. From left to right: auto-stereoscopic displays, motion-tracking set and haptic device.

III. VR APPLICATIONS

VR applications have been developed for several areas. Since the 90's pilots of civil aviation develop their abilities in VR based flight simulators. These systems are mounted under movable platforms and can simulate several airports, weather conditions and emergency situations [2]. The arts represent another emerging area for VR applications. In this case, systems have been constructed as a medium of expression for artistes and virtual museums become to be available over the Internet [7].

For medical education, applications based on VR are developed to the teaching of anatomy through three-dimensional atlases [8][9]. By a 3D visualization of the anatomy, students also can understand important physiological principles [10][11]. In the surgical simulation area, VR offers uncountable possibilities and uses computers for training, evaluation and certification [12]. Initially, the first simulators were limited due to the low graphical resolution and the lack of realistic devices for interaction. Nowadays, a new generation of systems offers interactive models and incorporates haptic devices [13].

In 1998 was presented a simulator for the identification of pathologies in the prostate through palpation using a haptic device [14]. Previously, another simulator already allowed the identification of subcutaneous tumors by the use of a haptic device [15]. In the field of veterinary, applications based on VR for rectal touch of bovines [17] and identification of tumors in equines [17] were already developed for educational purposes.

Recently, VR simulators had been developed for training in laparoscopy [18], arthroscopy [19] and many other specialties, as pediatric training of bone marrow harvest [20]. All these systems integrate several techniques divided according to their functionalities as: collision detection, force feedback, volumetric reconstruction, evaluation and ergonomics.

Besides the many systems for medical education and training, there isn't any application related to the teaching of

gynecological exam and identification of cervix pathologies. This way, it was observed the possibility of use of VR technologies to help students to training the visual and the palpation phase of this exam.

IV. THE SITEG SYSTEM

THE SITEG - Interactive System for Training in Gynecological Examinations - is a VR based system to support medical training in the diagnosis of pathologies related to cervical cancer. It offers an environment that presents the two phases of a gynecological exam.

A traditional gynecological exam is composed by a visual phase and by a palpation phase. In the visual phase, the doctor introduces a tool called speculum in the patient vagina to observe the aspect of the vagina walls and cervix. Coloration and presence of lesions or warts are some of the features observed. After that, the doctor removes the speculum and performs a digital examination of the internal portion of the vagina and cervix. At this phase, no visual information is available and the doctor must feel the vagina and cervix tissue properties to identify the presence of any lump or wart.

The main problem in the traditional method of training for gynecological procedures is in the digital exam. It happens because the only way that students acquire knowledge about this phase is performing an exam during the medical residence. Because there are different pathologies and several stages with different symptoms for each one, some cases are rare and sometimes do not occur during the medical residence. It produces an incomplete knowledge.

The SITEG intends to solve this problem by the presentation of all the main pathologies related to cervical cancer and their stages. As in the traditional gynecological exam, the SITEG simulates the two phases of the exam and allows the student (user) to view and touch the virtual models.

Because SITEG is an educational tool, it allows the student to examine pathologies known (exam module) or to examine and diagnose pathologies unknown (diagnosis module). In the second case, an evaluation tool is attached to the system to assess the user performance. This tool compares the user diagnosis with the correct diagnosis. Figure 2 shows the two modules that compose the system.

Previous studies show that the papilloma human virus (HPV) and the Herpesvirus Type II (HSV or Herpes) are the main pathologies that can impact in the development of cervical cells that cause the cervical cancer. The papilloma human virus (HPV) is present in ninety four percent of the cases of cancer uterine [21]. Based on these facts, the first prototype of SITEG supports the training and evaluation of normal cervix, Herpes and HPV cases.

V. DESIGN

THE development of the SITEG was based on the analysis of four factors: the design of the models to be used, the generation and control of the graphical scene (visual), generation and control of the haptic scene (tactile) and the

design of the evaluation tool. The models were composed to represent the external female genital, the vagina, the cervix, and the speculum.

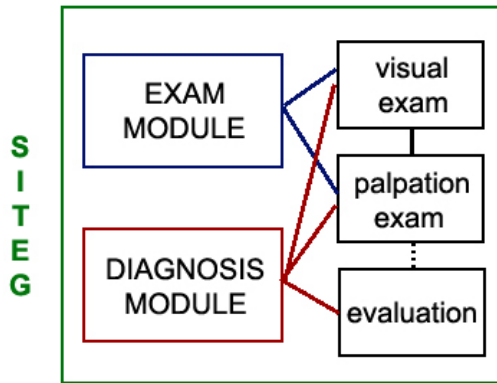


Fig. 2. The SITEG modules: Exam module presents an identified pathology and the Diagnosis module presents an unidentified pathology and contains an evaluation tool.

The models are used for the graphical scene and for the haptic scene in separate rendering processes. That happens because two scenes, responsible to deal with each sense, compose the system. Then, the system was composed for a class responsible to import the models (data class), a class responsible for the processing and visual presentation of these models (visual rendering class), a class responsible for the generation, control and haptic presentation of the models (haptic rendering class) and, finally, a class responsible for the evaluation of the user (user evaluation class) (Figure 3).

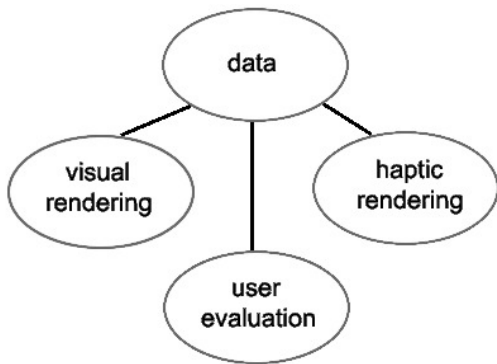


Fig. 3. SITEG classes.

The data class is responsible for reading and import of the models. It also contains the virtual world dimensions and models features, as their color and material properties. The material properties are related to the visual and to the haptic properties. The three other classes will use models information present in the data class.

The visual rendering class will generate and control the visual scene. In this class the visual world dimensions are defined, the models are positioned inside it, as well as light sources and the representation of the haptic device cursor. This class will perform all the visual rendering process and it will

controls the routines of generation of the stereoscopic pairs and supervise all the interactive modifications that can be made in the scene. It is also this class who will attribute textures to the models, what will allow simulating different pathologies.

The haptic rendering class will deals with the haptic scene to create a haptic world and to generate haptics objects from the information of geometry supplied by the data class. The objects will also receive the material properties related to the tissues. The routines to calculate the feedback forces and to return these forces to the haptic device are also included in this class.

The user evaluation class will analyze the user's information collected during the simulation. It will be attached to the diagnosis module and will provide an objective evaluation by the comparison of the diagnosis informed by the user with the correct one.

For a realistic simulation, the SITEG integrates specific devices to provide immersion and interaction for the user. For the visualization are available three different modes: monoscopic, stereoscopic by light polarization and stereoscopic by light obstruction. Two of them allow stereoscopic view and depends on polarized glasses or shutter glasses (Figure 4). This diversity of visualization modes is important because makes the user free to choose the view mode according to the device he owns.

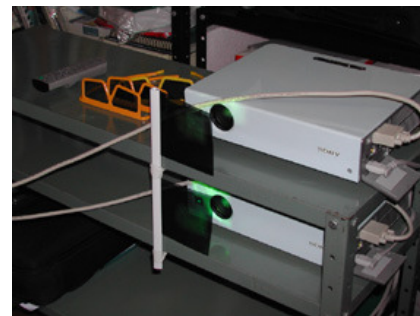


Fig. 4. Polarized glasses and projection system used to stereoscopic view in SITEG.

The interaction is performed by the use of a mouse and a haptic device. In this case, the haptic device will provide all the physical sensations related to the touch during the simulation (Figure 5). It is a 6DOF (degrees-of-freedom) device and allows three-dimensional interaction and force-feedback in the axis X, Y and Z. The device doesn't have a visual representation during the visual exam. However, he represents the doctor's finger during the palpation exam. For that, a texture of a finger is used over a crossed-plane graphical object (Figure 6).

Once the system was designed to present a combination of theoretical and practice learning, the theory about the exam is presented in the right side of the graphical window. The left side contains the model that the user can interact.



Fig. 5. Haptic device used in SITEG.

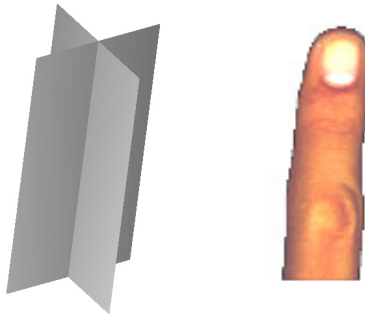


Fig. 6. The graphical object used to represent the haptic device and the texture of finger applied over each plane.

VI. IMPLEMENTATION

THE programming language used in the SITEG is C++ and the OpenHaptics API to program the haptic device. These tools were chosen due their total compatibility with the graphic library OpenGL, necessary to generate all graphical scenes. All the system is developed using free software.

The simulation was programmed to provide the two phases of training of a gynecological exam. The visual phase presents the cervix image when observed with the aid of a speculum. At this moment, the haptic device can be used to position a light source to improve the visualization of the cervix. After collect visual information, the user can select the palpation exam. During the palpation exam the user will only see the external female genital. By the manipulation of the haptic device, the user should enter and touch the vagina walls and touch the cervix to identify any abnormalities. When the exam module is active, the user previously knows what is the pathology presented and should learn how is its visual and tactile features. But, when the diagnosis module is active, the user doesn't know what is the pathology and should collect visual and tactile information in both modules to compose his diagnosis. His impressions will be confronted with the correct diagnosis in the final evaluation, when the pathology and its stage will be presented.

VII. SYSTEM CALIBRATION

TO calibrate the tissues properties of the models presented in SITEG, a calibration tool was implemented. In this tool a doctor can choose material properties. In the case of the visual properties, the doctor can observe several textures and select the correct one for each pathology at a different stage. For the tactile properties, a refining process was defined. The default material properties for each pathology were based on the impressions provided by a doctor. These impressions were collected for normal, HPV infection and Herpes infection cases. For that, information about cervix and vagina walls color, their textures and their viscosity where enumerated as shows Table I.

TABLE I
VISUAL AND TACTILE PROPERTIES FOR NORMAL, HPV INFECTION AND HERPES INFECTION CASES, ACCORDING TO A DOCTOR DESCRIPTION.

Case / Pathology	Cervix and Vagina Walls Coloration	Texture	Viscosity	Cervix Elasticity
Normal	rosy	similar to buccal mucous membrane	smooth	Similar to an orthopedic rubber
Herpes	white	spongy	soft bubbles	very soft
HPV	semi-transparent white	irregular	solid bubbles	very soft
Inflamed	red	similar to buccal mucous membrane	smooth	hard/tense

This information was used to implement the first values of the tactile calibration tool. Three visually identical spheres with different tactile attributes compose it. By the use of the haptic device, the doctor can touch the spheres and select the one whose properties are most similar to the found in a real gynecological exam. After that, the properties of the spheres are refined and the process is repeated. The calibration stops when were defined all the properties of the pathologies presented in the SITEG. Finally, the values obtained are moved to the simulator.

VIII. RESULTS

AT this moment, the SITEG offers the study of normal, HPV infection and Herpes infection cases. The HPV and Herpes were choose because to their relation to the cervical cancer incidence [21].

The system interface shows a window where graphical and textual information are simultaneously presented. The textual window describes the case/pathology presented. This window also is used to inform the user how to interact with the system. The Figure 7 shows the menu sequence available for user to select the module for simulation.

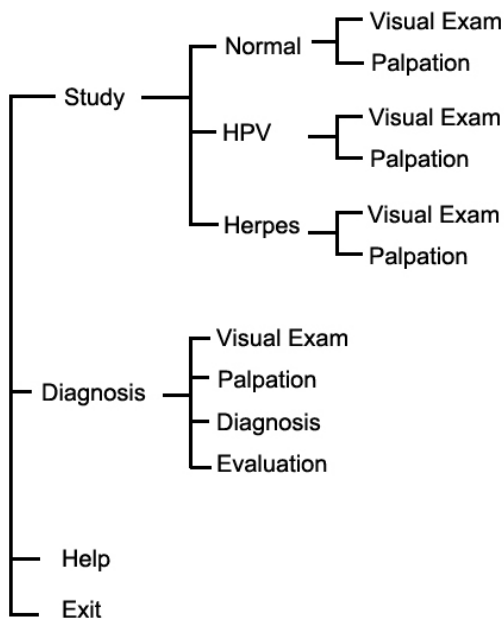


Fig. 7. Menu structure of SITEG.

Figure 8 shows the simulation of the visual exam. In this case is possible to observe the speculum inserted in a vagina model and the cervix. At this moment, the haptic device doesn't has a visual representation and its positioning is used to position a light source.

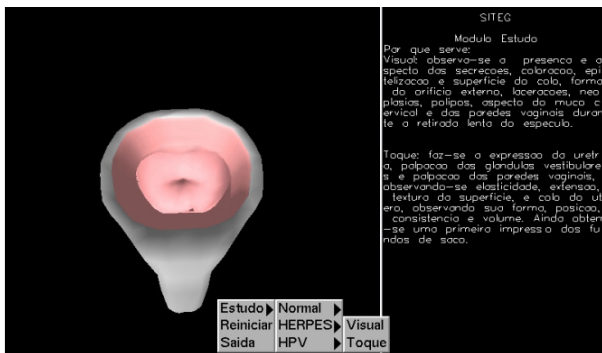


Fig. 8. Execution of the visual exam phase. The left portion of the window shows the cervix and the internal portion of vagina with the speculum inserted. At right are provided descriptions of what should be observed in the visual exam and the pathology (if in the study module).

Figure 9 shows the visualization of external female genital for the palpation exam. This image is the only visual information provided. The finger is the representation of the haptic utilized by the user to perform the palpation of the tissues inside the vagina and identification of cervix features.

IX. CONCLUSIONS

THIS article presents the SITEG system, a VR based application for education and training in gynecological exam. As feature the SITEG presents low cost due its complete development using free software. It allows the diffusion of this type of technology for education.

The main advantage of a VR based system for education in gynecological exam is the offer of several cases and pathologies for training without any risk or discomfort for students and patients. Besides, the student can learn about the different stages of a pathology as if he was performing a real exam.

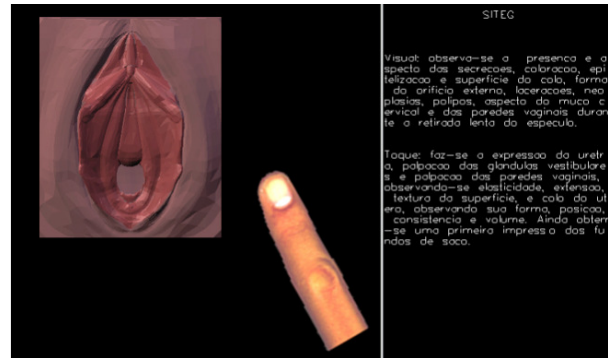


Fig. 9. Execution of the palpation exam. The left portion of the window shows external female genital. The finger is the graphical representation of the haptic device manipulated by the user.

The environment of SITEG is interactive and offers information to assist the user during the simulation. Because the interface and interaction are intuitive, no previous knowledge about computers or devices is necessary. By this use, the student can learn pathologies and practice his skills in diagnosis. As an education tool, SITEG also offers support for the VirtWall platform [22]. It allows its use in classroom for shared view.

Further works are related to the insertion of a subjective evaluation tool to not only compare the user diagnosis with the correct, but also monitor user interactions, as location and applied forces, to classify his dexterity and abilities [23].

Nowadays, new stages of the HPV and HERPES, besides other pathologies, are being included in the SITEG.

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