ONLINE TRAINING EVALUATION IN VIRTUAL REALITY SIMULATORS USING POSSIBILISTIC NETWORKS

Ronei Marcos de Moraes[1], Liliane dos Santos Machado[2]

Abstract *— Systems based on virtual reality are used in training many areas of human activities. In general, these kinds of training are performed to know the user's skills. An user is immersed into a virtual world to have realistic training and realistic interactions with that world, as he/she should made in real tasks. An online evaluation system allows to the user improve his learning because it can identify, immediately after the training, where he committed mistakes or presented low efficiency. In this paper, it was used an approach to online training evaluation based on a Possibilistic Networks. Those networks were used to model and classification of simulation in N pre-defined classes. Possibilistic Networks are a generalization of probabilistic networks, when fuzzy sets are used.*

Index Terms — Evaluation Systems, Possibilistic Networks, Online Training Evaluation, Training Based on Virtual Reality.

INTRODUCTION

Since World War II, training systems based on virtual reality (VR) have been used [2]. Since that time, the user is immersed into a virtual world to have realistic training and realistic interactions. The firsts systems were used to train pilots for combat. Nowadays, training systems based on VR are used to several goals. However, just with execution the training is not enough to know the quality of user’s skills. Several kinds of training based on VR use to record the user actions in videotapes to post-analysis by experts [1]. In these cases, the user receives his evaluation after some time. According to didactical aspects, probably after some hours the user will not remember his exact actions what will make difficult the use of the evaluation information to improve his performance. Besides of that, several kinds of training cannot be only classified as bad or good due to its complexity. Then, the existence of an online evaluation tool incorporated into a simulation system based on virtual reality is important to allow the learning improvement and users evaluation [5]. An online evaluation system allows the user to improve his learning because it can identify, immediately after the training, where mistakes occurred or actions presented low efficiency.

Just a few years ago were proposed the first methodologies for training evaluation. Specific evaluation methodologies for training through virtual reality simulators are still more recent. As VR simulators are real-time systems, an evaluation tool must continuously monitor all user interactions and compare his performance with pre-defined expert's classes of performance. It is more interesting the use of online evaluation tools due the fact that these methods allows the user to easily remember his mistakes and learn how to correct them.

In medicine, some models for online evaluation of training have been proposed [5,11,13,14,15]. The main problems related to online training evaluation methodologies applied to VR systems are the computational complexity and the accuracy. An online evaluation tool must have low complexity to do not compromise VR simulations performance, but it also must have high accuracy to do not compromise the user evaluation. In particular, some methods based on conexionist models were also proposed [7,8, 16,17,18,19,20,21].

In this paper, it is proposed a new evaluation tool based on Possibilistic Networks [3]. This approach can lead with requirements of an evaluation system for training based on VR.

TRAINING BASED ON VIRTUAL REALITY SIMULATORS

Virtual Reality refers to real-time systems modeled by computer graphics that allow user interaction and movements with three or more degrees of freedom [2]. More than a technology, VR became a new science that joins several fields as computers, robotics, graphics, engineering and cognition. VR worlds are 3D environments, created by computer graphics techniques, where one or more users are immersed totally or partially to interact with virtual elements. The realism of a virtual reality application is given by the graphics resolution and by the exploration of users senses. Mainly, special devices stimulate the sight, hearing and touch. As example, head-mounted displays (HMD) or even conventional monitors combined with special glasses can provide stereoscopic visualization, multiple sound sources positioned provides 3D sound, and touch can be simulated by the use of haptic devices [9,26].

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Virtual reality systems for training can provide significant benefits over other methods of training, mainly in critical medical procedures. In some cases, those procedures are performed without any kind of visualization and the only information received is noticed by the touch sensations provided by a robotic device with force feedback. These devices can measure forces and torque applied during the user interaction [26] and these data can be used in an evaluation [5,24]. A specific kind of haptic device, as the presented in Figure 1, is based on a robotic arm and provides force feedback and tactile sensations during user manipulation of objects in a three dimensional scene. This way, user can feel objects texture, density, elasticity and consistency. Since the objects have physical properties, a user can identify them in a 3D scene (without see them) by the use of this kind of device [9]. This is especially interesting in medical applications to simulate proceedings in which visual information is not available. One of the main reasons for the use of such haptic devices in medical applications is their manipulation similarity when compared to real surgical tools.

FIGURE. 1
HAPTIC DEVICE USED IN VR SYSTEMS.

EVALUATION IN VIRTUAL REALITY SIMULATORS

Evaluation of simulations is necessary to monitor the training quality and provide some feedback about the user performance. User movements, as spatial movements, can be collected from mouse, keyboard and any other tracking device. Applied forces, angles, position and torque can be collected from haptic devices [26]. Then, virtual reality systems can use one or more variables, as the mentioned above, to evaluate a simulation performed by user, as is showed in the Figure 2.

A training simulator based on virtual reality and its evaluation subsystem are interdependent subsystems, which works simultaneously. All subsystems of a simulator (visualization and interaction) and assessment subsystem works together inside of a same computer system. Thus, general performance of simulation must guarantee always to run in real time [2]. Then, the evaluation subsystem must obey an important restriction: it must work without compromise the simulator performance and its realism. This way, the research of evaluation systems for complex training, in which it is necessary to monitor a large number of variables simultaneously, is strongly dependent of four factors: a) computational complexity of the virtual reality environment; b) computational complexity of the assessment method; c) accuracy of method, once validated its basic assumptions for the specific problem and d) the computer system available to execute training environment and assessment subsystem. The balance of those four factors is not easy to solve. Very realistic virtual reality environments demand high computational costs, as well as may demand interactions using haptic devices and the use of deformable models. These requirements have priority over other subsystems as the evaluation. A solution is use methods of low computational cost for evaluation.

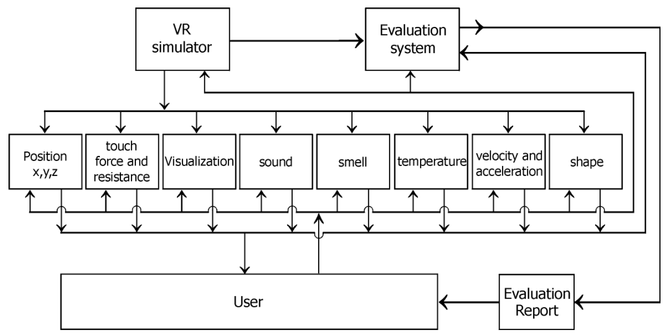

FIGURE. 2
ARCHITECTURE OF AN EVALUATION SYSTEM FOR TRAINING BASED ON VIRTUAL REALITY.

Some simulators for training present a method of evaluation. However they just compare the final result with an expected result or are post-analyses of videotape records [1]. Recently, some models for offline or online evaluation of training have been proposed, some of them use Discrete Hidden Markov Models [24] or Continuous Hidden Markov Models [25] to modeling forces and torque during a simulated training in a porcine model. Machado et al. [5] proposed the use of a fuzzy rule-based system to online evaluation of training in virtual worlds. Using an optoelectronic motion analysis and video records, McBeth et al. [10] acquired and compared postural and movement data of experts and residents in different contexts by use of distributions statistics. Moraes and Machado proposed several methods for online evaluation [7,12,13,15,16]. They also proposed a methodology to automatically assess a user's progress to improve his/her performance in virtual reality training systems [14] using statistical measures and models (time dependent or not) as well as a fuzzy expert system. After that, Morris et al. [22] suggested the use of statistical linear regression to evaluate user's progress in a bone surgery.

In this paper, we propose a new system for evaluation based on Possibilistic Networks. The system uses a vector of information, with data collected from user interactions with virtual reality simulator, and these data are compared by the evaluation system with *M* pre-defined classes of performance. To test the method proposed, we are using a bone marrow harvest simulator [5]. This simulator has as goal to training new doctors to execute the bone marrow harvest, one of the stages of the bone marrow transplant. The procedure is done blindly, performed without any visual feedback, except the external view of the patient body, and the physician needs to feel the skin and bone layers trespassed by the needle to find the bone marrow and then start the material aspiration (Figure 3). The simulator uses a robotic arm that operates with six degrees of freedom movements and provides force feedback to give to the user the tactile sensations felt during the penetration of the patient's body [5]. In the system the robotic arm simulates the needle used in the real procedure, and the virtual body visually represented has the tactile properties of the real tissues. The evaluation tool proposed supervised the user movements during the puncture and evaluated the training according to M possible classes of performance.

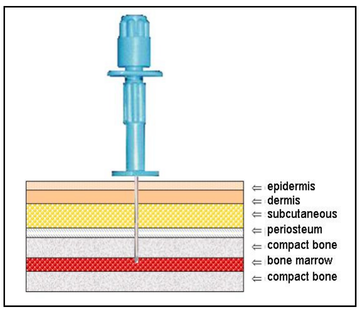

FIGURE. 3
THE TISSUE LAYERS TRESPASSED BY NEEDLE IN A BONE MARROW HARVEST.

EVALUATION TOOL BASED ON POSSIBILISTIC NETWORKS

This section presents the method for training evaluation, based on Possibilistic Networks. For reader's better understanding, we first present a short review about Bayes networks. After that, we present the Possibilistic Networks.

Bayesian Networks

A Bayesian network is a probabilistic model, which can represent a set of probabilities distributions from all variables in a complex process and also establish their relationships [23]. Formally, a Bayesian network is defined as directed acyclic graphs, denoted by G and a joint probability distribution denoted by P. The graph $G=(X,L)$ is a set of nodes and oriented arcs L, where nodes represent variables X in process and oriented arcs encode conditional dependencies between that variables [23]. The dependencies are modeled by specific conditional probabilistic distributions [4] for an attribute given the parent attributes in the network.

Formally, let be the classes of performance in space of decision $\Omega=\{1,...,M\}$ where M is the total number of classes of performance. Let be w_i, $i \in \Omega$ the class of performance for an user. Let be a probability distribution P, which represents the joint domain of a set of n attributes $X=\{X_1, X_2, ..., X_n\}$, obtained when a training is performed .Thus:

$$\begin{aligned} P(X_1, X_2, ..., X_n, w_i) &= P(w_i)\, P(X_1, X_2, ..., X_n \mid w_i) = \\ &= P(w_i)\, P(X_1 \mid w_i)\, P(X_2, ..., X_n \mid w_i, X_1) \\ &= P(w_i)\, P(X_1 \mid w_i)\, P(X_2 \mid w_i, X_1)\, P(X_3, ..., X_n \mid w_i, X_1, X_2) \\ &\dots \\ &= P(w_i)\, P(X_1 \mid w_i)\, P(X_2 \mid w_i, X_1) \dots P(X_n \mid w_i, X_1, X_2, ..., X_{n-1}) \end{aligned} \tag{1}$$

It is possible simplify this methodology making the assumption that features are statistically independents. This assumption is called Naive Bayes and it simplifies the equation above, which can be rewritten as:

$$\begin{aligned} P(X_1, X_2, ..., X_n, w_i) &= \\ &= P(w_i)\, P(X_1 \mid w_i)\, P(X_2 \mid w_i) \dots P(X_n \mid w_i) \end{aligned} \tag{2}$$

unless a scale factor S, which depends on $X_1, X_2, ..., X_n$, from the equation (2):

$$\begin{aligned} P(X_1, X_2, ..., X_n, w_i) &= \\ &= (1/S)\, P(w_i)\, \Pi^n_{k=1}\ P(X_k \mid w_i) \end{aligned} \tag{3}$$

Then, the classification rule for Naive Bayes is done by:

$$X \in w_i \ \text{ if } \ P(w_i)\, \Pi^n_{k=1}\ P(X_k \mid w_i) > P(w_j)\, \Pi^n_{k=1}\ P(X_k \mid w_j) \quad \text{for all } i \neq j \tag{4}$$

Possibilistic Networks

Formally, a Possibilistic Network is defined by (Y,L,π), where Y is a set of nodes, L are oriented arcs, and π is a possibility distribution. As in Bayesian Networks, the possibility distribution π represents the joint domain of a set of n attributes $X=\{X_1, X_2, ..., X_n\}$, obtained when a training is performed . According to Borgelt and Gebhardt [3] and due to the symmetry in the definition of conditional possibility distribution:

$$\pi(w_i \mid X_1, X_2, ..., X_n) = \pi(X_1, X_2, ..., X_n \mid w_i) \tag{5}$$

It is possible simplify this methodology making the assumption that features do not have any possibilistic interactions. This assumption is similar to the statistical independency. Besides, as the possibilistic approach is simpler than Bayes rule, and it is not necessary take account of a normalization constant or of prior class probabilities. This approach is called Naive Bayes Style Possibilistic Network by [3]. So, the equation (5) can be rewritten as:

$$\begin{aligned} \pi(w_i \mid X_1, X_2, ..., X_n) &= \\ &= \min \{\pi(X_1 \mid w_i), \pi(X_2 \mid w_i), ..., \pi(X_n \mid w_i)\} \\ &= \min_N \{\pi(X_1 \mid w_i)\}, \text{ where } N=1,...,n. \end{aligned} \tag{6}$$

Then, the classification rule for Naive Bayes Style Possibilistic Network is done by:

$$X \in w_i \quad if: \quad min_N \{\pi(X_1 \setminus w_i)\} > min_N \{\pi(X_1 \setminus w_j)\} \text{ for all } i \neq j \text{ and } i, j \in \Omega \tag{7}$$

THE EVALUATION TOOL

The evaluation tool proposed should supervise the user's movements and other parameters associated to them. The system must collect information about positions in the space, forces, torque, resistance, speeds, accelerations, temperatures, visualization position and/or visualization angle, sounds, smells and etc. The virtual reality simulator and the evaluation tool are independent systems, however they act simultaneously. The user's interactions with the simulator are monitored and the information is sent to the evaluation tool that analyzes the data and emits a report on the user's performance at the end of the training. Depending on the application, all those variables or some of them will be monitored (according to their relevance to the training).

The virtual reality system used for the tests is a bone marrow harvest simulator [6]. In a first movement on the real procedure, the trainee must feel the skin of the human pelvic area to find the best place to insert the needle used for the harvest. After, he must feel the tissue layers (epidermis, dermis, subcutaneous, periosteum and compact bone) trespassed by the needle and stop at the correct position to do the bone marrow extraction. In our VR simulator the trainee interacts with a robotic arm and his/her movements are monitored in the system by some variables [6]. For reasons of general performance of the VR simulator, were chosen to be monitored the following variables: spatial position, velocities, forces and time on each layer. Previously, the system was calibrated by an expert, according to *M* classes of performance defined by him. The calibration process consists in to execute several times the procedure and to classify each one according to classes of performance. The number of classes of performance was defined as $M=3$: 1) correct procedures, 2) acceptable procedures, 3) badly executed procedures. So, the classes of performance for a trainee could be: "you are well qualified", "you need some training yet", "you need more training".

The information of variability about these procedures is acquired using Naive Bayes Style Possibilistic Network. In our case, we assume that the font of information for w_i classes is the vector of the sample data *D*. The user makes his/her training in virtual reality simulator and the Evaluation Tool based on Naive Bayes Style Possibilistic Network collects the data from his/her manipulation. So, when a trainee uses the system, his performance is compared with each expert's class of performance and the Evaluation Tool based on Naive Bayes Style Possibilistic Network assigns the better class, according to the trainee's performance. At the end of the training, the evaluation system reports the classification to the trainee.

CONCLUSIONS AND FUTURE WORKS

In this paper we presented a new approach to online training evaluation in virtual reality simulators. This approach uses an Evaluation Tool based on Naive Bayes Style Possibilistic Network and solves the main problems in evaluation procedures: use of continuous variables, low complexity and high accuracy. Systems based on this approach can be applied in virtual reality simulators for several areas and can be used to assess a trainee into classes of learning giving him a status about his performance.

As future work, we intend to test and to make a statistical comparison between others methodologies and the methodology proposed in this paper.

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