MULTIPLE ASSESSMENT FOR MULTIPLE USERS IN TRAINING BASED ON VIRTUAL REALITY

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

Abstract *— Nowadays, there are several kinds of training based on virtual reality. In most of them, only one user can be trained each time. With recent computational advances, several interaction devices can be used by different users that share a same virtual world, allowing simulating more realistic environments, as surgical rooms. In order to deal with this feature, assessment systems must be generalized to evaluate individually all users of the simulation and allow knowing aspects of their interactions. In this paper we propose a new assessment system for training based on virtual reality that can evaluate more than only one user.*

Index Terms — Multiple Assessment System, Training based on Virtual Reality, Fuzzy Expert System, Statistical Measures, Statistical Models.

INTRODUCTION

Virtual Reality (VR) systems have been used since the 2nd World War for training of several procedures [37]. Nowadays, realistic training systems have been developed in order to provide training of procedures in several areas [8]. The features found in training systems based on virtual reality can be the 3D environments composed by objects with topologies and behaviors similar to real objects, the interaction ways to deal with this world, the possibility of perform a training as much as necessary without risk or damage, among others. Systems for different modalities in medicine have been developed as training in laparoscopy [41], prostate examination [7], ocular surgery [21], bone marrow harvest [17], gynecological exam [19] and bone surgery [32]. The goal of most of these systems is to provide a training environment similar to a real procedure environment by the use of devices and techniques, which explore the human senses. All these systems can provide training for only one user at once. However, some procedures need to be performed by more than one person.

Training systems based on VR for simultaneous use by more than one user in complex training environments are in planning, as virtual surgery rooms for several purposes of training. The advances of cluster machines, improvements of speed of video cards, machines, and networks will provide training system for multiple users simultaneously in a few years at low cost. Other important advance is the speed of input/output devices for virtual reality systems, as haptic devices. Nowadays, is possible to connect more than one interaction device on one single computer.

Although the possibilities of training which can be simulated in VR systems, any kind of training has a little value if the trainee cannot know about his/her performance. If a user knows his/her mistakes, he/she can improve his/her learning about that. As it is known, several kinds of training based on VR use to record the user performance in videotapes to post-analysis by experts [7]. After some time, the user receives his assessment. This is a problem because after some hours the user will probably not remember his exact actions when he/she was performing the simulation. This fact makes difficult the use of the assessment information to improve users' performance. Besides of that, several kinds of training cannot be simply classified as bad or good due to its complexity. Then, the existence of an on-line assessment tool attached to a simulation system based on VR is important to allow the learning improvement and users assessment.

This paper presents a quick review about assessment in VR training systems for single users and proposes a method for assessment in collaborative training environments for simulators based on VR.

ASSESSMENT IN VIRTUAL REALITY SIMULATORS

The first methodologies for automatic assessment of training have been proposed just a few years ago. In this section it will be presented a brief overview about assessment methodologies for training based on virtual reality. It can be noticed that several of them have potential for applications in other research areas too.

Basically, assessment methods can be divided in off-line and on-line. Off-line methods can be defined as methods not coupled to VR systems, whose assessment results are provided some time (which can minutes, hours or days) after the end of the VR-based training. On the other hand, online assessment methods are coupled to the training system and collects user data to provide a result of his/her performance at the end of the simulation.

In medicine, some models for off-line [22, 35, 36] or on-line [16, 18, 19, 23, 24, 26, 27, 28, 29, 30] assessment of training have been proposed. Some of them use Discrete Hidden Markov Models (DHMM) [35] or Continuous Hidden Markov Models (CHMM) [36] to modeling forces

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and torque during a simulated training in a porcine model. Machado et al. [16] proposed the use of a fuzzy rule-based system to on-line evaluation of training in virtual worlds. Moraes and Machado [23] proposed the use of CHMM for on-line evaluation in any virtual reality simulators. After that, the same authors proposed another approach for on-line evaluation learning using Fuzzy Hidden Markov Models (FHMM) [24]. Using an optoelectronic motion analysis and video records, McBeth et al. [22] acquired and compared postural and movement data of experts and residents in different contexts by use of distributions statistics. Moraes and Machado proposed the use of Fuzzy Gaussian Mixture Models [27], Neural Networks [18] and Evolving Fuzzy Neural Networks [29], Maximum Likelihood [26] and recently Fuzzy Bayes Rule [30], among others. They also proposed evaluators with two-stage [28].

Some methodologies had been proposed to perform continuous assessment to the user. Moraes and Machado [25] proposed use of expert systems and statistical tools to perform continuous assessment of the user in several trainings in VR-simulator. Morris et al. [32] suggest the use of statistical linear regression to evaluate user's progress in a bone surgery.

Because 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. Besides of the quantity of methodologies proposed in literature, they are dedicated to assess only one user at once. At this moment, methodologies to monitor multiple users in training in complex training environments based on virtual reality have not been found in literature.

Multiple Assessment for multiple Users in Virtual Reality Simulators

Computational systems for multiple users have been developed since 90's, as RB2 [5], DIVE [9], MR Toolkit [38], VR-DECK [10], VEOS [6] and RAVEL [14], and some of them present support for haptic devices. Systems to provide interaction among multi-user have been proposed too. Arai et al. [2] proposed an intelligent system to assist a remote physician by Internet using a special haptic device. Baier et all [3] proposed a system for telepresence using haptic and visual interactions. Ehnes et al. [11] adapted a off the shelf system for collaborative tasks of drawing, sketching and painting. Recently, systems for multi-user were developed for collaboration [33][42].

For medicine, some systems for surgery were proposed [15] [31]. Then, off the shelf systems are available as the Virtual Surgery Table [4] which provide interactions for two users, simultaneously.

The main differences of training systems based on virtual reality for multiple users are:

- increase of complexity of the virtual reality system - use of clusters of computers or a computer capable to: generate realistic multiple views, support changes in virtual environments for multiple users and support assessment system (in the case of training based on Web, a high speed peer-to-peer network can be enough to perform training, even when using virtual reality);
- high speed peer-to-peer network for communication among computers without compromise the simulation;
- eventually, more than one haptic device installed in a computer;
- tracking systems for each user in training.

The most common problem in distributed systems based on network or Web, for multi-user interactions, is lthe atency [34]: users may have different views in the shared workspace which damages the users' performance involved in the simulation.

For user assessment, the main problems related are the computational complexity and the accuracy, even when only one user is been trained. An on-line assessment system for single user must have low complexity to do not compromise VR simulations performance, but it must have high accuracy to do not compromise the user evaluation [16].

Due to several specific necessities for multi-user training, it is required a different approach for the assessment system. The requirements are:

- to monitor all users in training according relevant variables to the training;
- in multi-user environment some tasks must be completed by specific users and according a specific schedule;
- take measures of specific interactions among users during the time of simulation;
- take in to account the time of assessment;
- to create a user profile and a group profile;
- to present low complexity to do not compromise VR simulations performance, but present high accuracy.

In the literature, some kinds of assessment have been proposed. Gande and Devarajan [12] have used an Instructor/Operator Station to monitor user movements and to increase or decrease the degree of difficulty in a simulation. Their Instructor station is able to evaluate and monitor the resident's performance, based on the specifications mentioned, to generate training effectiveness reports. The GeRTiSS system [1] can provide to the user an assessment report at the end of simulation. That report contains: total time of intervention, number of cuts and cauterizations, among other information. The surgeon can use this information to perform an assessment of his intervention. The WebSET system [13] provides test scenarios in which the users can make simulations. In this system, the users are evaluated by the speed of answers, number of mouse movements, accuracy, making decisions and learning.

A Proposal for Multiple Assessment

A tool for multiple assessment must be interconnected with all users and must receive from them synchronized information about all variables of interest. An assessment system works coupled to a virtual reality simulator, as showed in the Figure 1 [27]. As an on-line assessment system, which should be capable to monitor user interactions while he/she operates the simulation system, a multiple assessment must be capable to monitor, simultaneously, the interactions of each user. In order to reach that, it is necessary to collect information about position in the space, forces, torque, resistance, speeds, accelerations, temperatures, visualization and/or visualization angle, sounds, smells, etc. To collect some information as force, force feedback, angles and torques, it is necessary to use specific devices to provide them, as the one presented in Figure 2. These information will be collected for each user in training system, as well as for all group, to be used to feed the assessment system. Additionally, a synchronization in time space is necessary for all users to measure interactions among them, to determine the ordering of tasks and to provide details of user's performance.

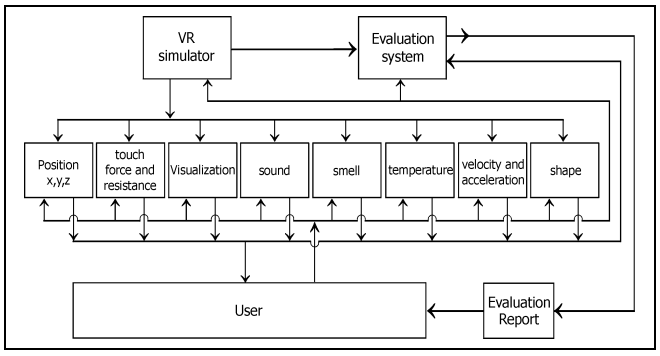

FIGURE 1.
Diagram of a VR Simulator with an Assessment System for a Single User.

User's interactions with the system are monitored and the information are sent to the assessment system which analyzes the data and emits, at the end of the training, an assessment report about the user's performance according pre-defined classes of performance. Therefore, a multiple assessment tool must be capable to monitor each user individually, as well as, all group. Then, at the end of simulation, another assessment report will be emitted about the group performance.

As mentioned above, several methods were proposed to assess single user in training based on virtual reality. Most of them were based on classical classifiers, as neural networks, maximum likelihood, mixture models, fuzzy sets, among others. However, besides the fact that several of them could be used in multiple assessment tasks, there are calibration problems for multiple users. To minimize those problems, a multiple assessment system based on a fuzzy expert system [5][20] is proposed in this paper. This way, a set of fuzzy rules of an expert system time dependent defines each one of the possible performance classes. This set is designed, for single users and for group, from specialists knowledge. Additionally, interaction variables will be monitored according to their relevance to the training. Then, each application will have their own set of relevant variables which will be monitored [27]. The same happens with relevant variables which measure interactions among users in the group.

FIGURE 2.
A robotic Device used to Provide Force Feedback in VR Simulators.

The methodology proposed for multiple assessment uses data collected from user interaction and group interactions during training to create user profile and group profile. That information is used to evaluate trainee and allows the improvement [39] of his performance in real tasks.

Our methodology makes an union of statistical tools and fuzzy rule based expert systems to construct an individual profile for trainee and for group. Statistical tools are programmed to make an automatic analysis of the database and construct statistical measures, tables, graphics and time dependent statistical models. From these information (statistical measures and parameters), the fuzzy expert system will create an individual user and group profiles and two kinds of report. These assessment reports present individual and group profiles and shows the performance of specific tasks with statistical measures, tables, graphics, models and some phrases in pseudo-natural language. Figure 3 shows the new methodology presented.

It can be observed that the Assessment System from Figure 1 has been changed and now it is called Individual Assessment System. To construct the Multiple Assessment System, the Group Assessment Tool, the Users and Group Profiles were also added. The new Multiple Assessment System creates two kinds of report: individual assessment report, for each user, and group assessment report. The first report is about the individual user performance on the training and the second assessment report is about group performance and the interactions among users during training.

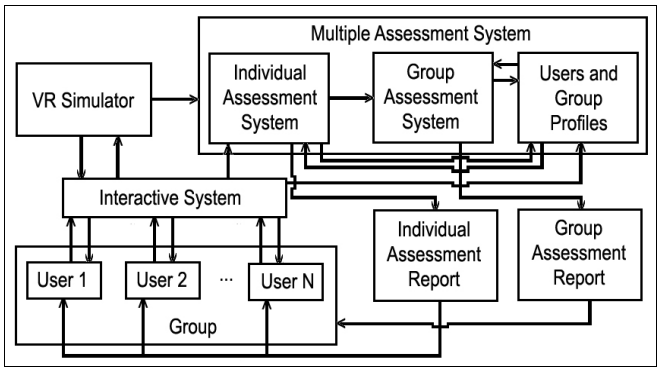

FIGURE 3.
DIAGRAM OF NEW ASSESSMENT SYSTEM WITH APPROACH OF CONTINUOUS ASSESSMENT.

This methodology for Multiple Assessment System can be used for several kind of training in medicine, as procedures in surgical rooms, training paramedics groups in emergency situations, etc. However, it is a generic methodology and can be used in training systems for other areas, as aeronautical simulators, maintenance group, managing of nuclear, thermoelectric, hydroelectric power plant, etc.

Unfortunately, this Multiple Assessment System can not be classified as online or offline as in single user assessment systems. As mentioned before, an online assessment system must generate reports immediately after of the end of training session. Sometimes, the Multiple Assessment System will be capable to do that, but in another cases it will be not. The main reasons for that involve: computers configuration, possible delay in networks, number of statistical time dependent models necessary to measure some variables, complexity of simulation and number of interactions.

CONCLUSIONS AND FUTURE WORKS

This paper presents a review for assessment systems for training based on virtual reality for single user. It was presented also the future of training based on virtual reality for multiple users with interactions among them. For this, are necessary new methodologies to allow the assessment of training for each user as well as for the group. In order to do that, was introduced a new methodology for multiple assessment for multiple users in training . This methodology is based on time-dependent fuzzy based rules expert system which uses input variables from training, statistical measures and time dependent statistical models in order to create measures of assessment for trainees and group performance. This Multiple Assessment System can create two kinds of report: an assessment report for individual user, about his/her performance on the training, and an assessment report about group performance and interactions among users during the training.

The proposed methodology can be used for several kind of training in medicine, as procedures in surgical rooms, training paramedics groups in emergency situations, etc. It is interesting to note that this Multiple Assessment System also can be used in other training situations when a group of trainees performs a task together.

The Multiple Assessment System cannot be classified online or offline as single user assessment systems due to computers configuration, possible delay in networks, number of statistical time dependent models necessary to measure some variables, complexity of simulation and number of interactions.

As future work, we intend to implement this Multiple Assessment System in a virtual reality system for training of multiple users. Additionally, we intend to make statistical comparison among users to identify improvements of learning when VR systems are used to replace traditional training methods.

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