NEURAL NETWORKS FOR ONLINE TRAINING EVALUATION IN VIRTUAL REALITY SIMULATORS

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Abstract *— In several research areas, virtual reality environments have been constructed for training objectives. The goal is to immerge the user into a virtual world to provide realistic training and realistic interactions. However, it is important to know the quality of training to provide a status of the user performance. An online evaluation system allows the user to improve his/her learning because it can identify, immediately after the training, where he/she committed mistakes or presented low efficiency. To evaluate the user's performance it is necessary collect data from training. In some applications, data collected from user's interaction cannot be adequate to classical statistical distributions. To solve that problem we propose the use of Neural Networks to online evaluation of procedures in virtual reality simulators. This approach is very simple and it can be used for Web-based simulation evaluation, using plug-ins or agents to collect information about the different variables of user's simulations.*

Index Terms — Artificial Neural Networks, Training Evaluation, Online Evaluation, Virtual Reality.

INTRODUCTION

The existence of an online evaluation tool in simulation system based on virtual reality is important to allow the learning improvement and users evaluation. Recently, new methods of evaluation for online training in virtual reality simulator have been proposed [2, 4, 5, 10, 12, 13, 14, 15, 16, 17, 19, 20]

In medicine, some models for offline or online evaluation of training have been proposed. However, great part of these approaches depends on large computational structure, which is very expensive to be available in some Medical Centers in Brazil and several other countries.

Simulators bases on virtual reality (VR) for training need high-end computers to provide realistic haptics, stereoscopic visualization of 3D models and textures. Online evaluators must have low complexity to do not compromise performance of simulations, but they must have high accuracy to do not compromise evaluation. The Artificial Neural Networks can be a good option to do an online evaluation, because they can obtain good accuracy models and they are simple too. We propose the use of the neural networks [9, 23] for an online training evaluator in virtual reality simulators.

VIRTUAL REALITY AND SIMULATED TRAINING

Virtual Reality refers to real-time systems modeled by computer graphics that allow user interaction and movements with three or more degrees of freedom [25]. More than a technology, virtual reality became a new science that joins several fields as computers, robotics, graphics, engineering and cognition. Virtual Reality 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 quality of the user experience in a virtual reality world is given by the graphics resolution and by the use of special devices for interaction. Basically, the devices stimulate the human senses as vision, audition and touch: head-mounted displays (HMD) or even conventional monitors combined with shutter glasses can provide stereoscopic visualization; multiple sound sources positioned provides 3D sound; and touch can be simulated by the use of haptic devices [6, 8].

There are many purposes for virtual reality systems, but a very important one is the simulation of procedures for training. Virtual reality systems for training provide significant benefits over other methods, mainly in critical procedures. One example of training based on VR systems is the flight simulators used for the pilots' training in the civil aviation [24]. In medicine, the use of virtual reality systems for training is beneficial in cases where a mistake could result in physical or emotional impact on patients. Systems for different modalities in medicine have been developed, as training in: laparoscopy [26], prostate examination [1], ocular surgery [7] and bone marrow harvest [3]. In some cases, the procedures are done without visualization for the physician, and the only information he receives is done by the tactile sensations provided by a robotic device with force feedback. These devices can measure forces and torque applied during the interaction [8] and these data can be used in an evaluation [2, 19].

EVALUATION IN VIRTUAL REALITY SIMULATORS

The evaluation of simulations is necessary to assess the training quality and provide some feedback about the user

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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 [21]. So, virtual reality systems can use one or more variables, as the mentioned above, to evaluate a simulation performed by user.

Some simulators for training have a method of evaluation. However they just compare the final result with the expected one or are videotape records post-analyzed by an expert [1]. Recently, some models for offline or online evaluation of training have been proposed, some of them use Discrete Hidden Markov Models (DHMM) [19] or Continuous Hidden Markov Models (CHMM) [20] to modeling forces and torque during a simulated training in a porcine model. Machado et al. [2, 4] proposed the use of a fuzzy rule-based system to online evaluation of training in virtual worlds. Moraes and Machado [12, 17] proposed the use of CHMM for online evaluation in any virtual reality simulators. After that, the same authors proposed another approach for online evaluation learning using Fuzzy Hidden Markov Models (FHMM) [13]. 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. Machado and Moraes proposed the use of Gaussian Mixture Models [14], Fuzzy Gaussian Mixture Models [15].

They proposed also two evaluator with two-stage: the first one using Gaussian Mixture Models and Relaxation Labeling [16] and after the Fuzzy Gaussian Mixture Models and Fuzzy Relaxation Labeling [5] to provide an online evaluation for simulators or training systems based on virtual reality.

In this paper, we propose the use of the neural networks for an online training evaluator in virtual reality simulators. The system uses a vector of information

To test the method proposed, we are using a bone marrow harvest simulator [3]. 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 donor 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. The simulator uses a robotic arm that operates with six degrees of freedom movements and force feedback to give to the user the tactile sensations felt during the penetration of the patient's body [11]. 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 should supervise the user movements during the puncture and should evaluate the training according to N possible classes of performance.

NEURAL NETWORKS

This section presents the Artificial Neural Networks (ANN) method for training evaluation. Basically, an ANN is a computational system using artificial neurons, which they are totally connected with others (synapses) .The main capabilities of ANN are:

- To learn by examples;
- Self-adapt for other problems
- Organization
- Generalization
- Robustness to the noise and
- Fail tolerance

Can be founded in the literature several applications for ANN with good results in statistical pattern recognition [22, 27].

There are several kinds of ANN, but several of them are based of Perceptron concept [23]. Figure 1 shows this concept and we can observe the linear combination of inputs X by weights W which results the output Y.

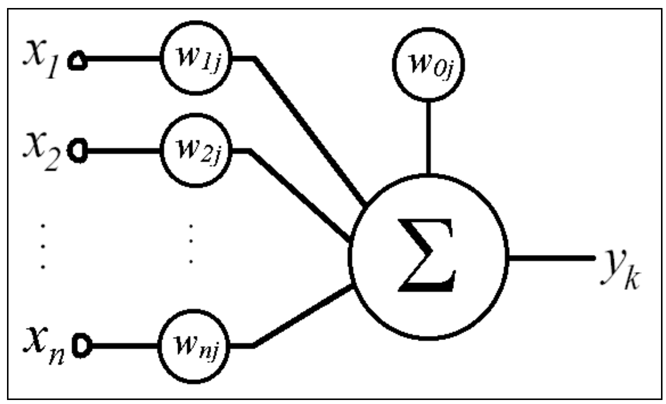

FIGURE. 1
CONCEPT OF PERCEPTRON.

The output y_k is done by:

$$y_k = w_{0j} + \Sigma^{n}_{j=1} x_i w_{ij} \qquad (1)$$

The activation function or threshold function maps a Perceptron to a pre-specified range. Four activation functions are commonly used: linear, ramp, step and sigmoid. The family of sigmoid functions is big, but the function:

$$S(x) = (1+e^{-x})^{-1} \qquad (2)$$

is known as logistic function and it is seen in statistics as the Gaussian distribution function.

In this paper, we use the Multi-Layer Perceptron (MLP) [23]. The Figure 2 shows the concept of MLP. We have an input layer X, with $x_1, x_2, \ldots, x_n$ inputs. We can have one or more hidden layers Z and an output layer Y, with $y_1, y_2, \ldots, y_k$ outputs.

We use the *Feedforward* topology [23], that is it allows flow of information in one direction. However, this topology has an inconvenient: we do not know about hidden layers errors. The solution for this problem is use *Error Backpropagation* supervised training method [23] for estimate weights of perceptron.

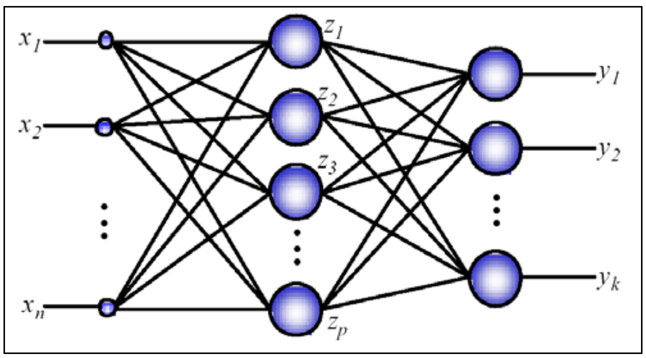

FIGURE. 2
CONCEPT OF MULTI-LAYER PERCEPTRON.

THE EVALUATION TOOL

The evaluation tool proposed should supervise the user movements and others parameters associated to it. The system must collect information about positions in the space, forces, torque, resistance, speeds, accelerations, temperatures, visualization and/or visualization angle, sounds, smells and etc. The virtual reality simulator and the system of evaluation are independent systems, however they act simultaneously. The user's interactions with the system are monitored and the information is sending to the evaluator system that analyzes the data and it 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.

In the virtual reality simulator the trainee must extract the bone marrow. In the first movement, he must feel the skin to find the best place to insert the needle. 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 system the trainee movements are monitored by variables as: acceleration, applied force, spatial position, torque and angles of needle.

For the evaluation an expert executes several times the procedure for each one of K classes of performance available, for example: "well qualified", "need some training yet", "need more training", "novice", etc. So, the information of variability about these procedures is acquired using Backpropagation trained MLP neural network and using activation function done by (2).

The y_k outputs from Backpropagation trained MLP neural network are normalized and converted in scores of performance of each class of performance y_{ko} and $y_{ko} \in [0,1]$.

$$y_{ko} = y_k / \{\Sigma^{K}_{i=1} y_i\}, \quad k = \{1, 2, \ldots, K\} \qquad (3)$$

The trainee's performance is labeling and trainee receives a report with all possible classes of performance and its respective score of performance, according (3).

CONCLUSIONS AND FUTURE WORKS

In this paper we presented a new approach to online evaluation in training simulators based on virtual reality using neural networks. This approach provides the use of continuous variables without lost of information. So, it solves the problem of low complexity of online evaluators, without compromise performance of simulator and with good accuracy evaluation.

Systems based on this approach can be applied in virtual reality simulators for several areas and can be used to classify the trainee into classes of learning giving him a real position about his performance, through the reports of performance of each training. In medicine, it provides an appropriate methodology for blind made procedures.

As future work, we intend to test and to make a statistical comparison between others kinds of neural networks for improve accuracy of evaluator.

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