

## Artificial neural networks as a technique for risk assessment of training critical activities by means of a virtual environment

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**Abstract**—Technology advances in recent years have allowed for the emergence of different teaching paradigms. New methodologies, as well as new systems and equipment, aim at enhancing the teaching-learning process. One of the concepts that represent such paradigms is often referred to as serious games, designed to place learners in a virtual scenario in which they must find the solution to a specific problem. This scheme serves as an incentive, for example, in the solution of a problem presented by a tutor in a Problem Based Learning (PBL) context. This paper presents a method for verifying user safety conditions during training of critical activities. The case portrayed here is the installation of a temporary bypass in a virtual electric power substation. The environment has been developed using the Unreal Game Engine 4®. For this end, an Artificial Neural Network (ANN) was used to detect violations in relation to safety distances. In this context, a brief review of the main applications of artificial intelligence (AI) in serious games was carried out. The virtual environment was modeled with the objective of being as immersive and accurate as possible in order to ensure that the trainees feel the context in which they have to work in real life.

**Keywords**-Serious Games, Neural Networks, Virtual Reality, Training of Critical Activities.

### I. INTRODUCTION

Recently, new methodologies, procedures and tools have appeared with the objective of enhancing learning processes [1]. The concept of *Education 4.0* aims to integrate online and offline approaches to create an environment conducive to experiential education. The *blended learning* aims the joint use of resources that really stimulate students' digital skills and intelligence [2].

Serious Games on Virtual Reality platforms can simulate scenarios and critical situations while challenging the user to make decisions. The language of games, interactions and immersion in the virtual environment are achieved through devices that allow the direct control of virtual objects

through the recognition of hand gestures or virtual reality goggles, the so-called *head mounted display*. This aims to promote greater engagement of the learner in solving the proposed problem [3], whether in the context of curricular content teaching or specific skills training [4]. In relation to training and professional qualifications, the use of Serious Games allows the training of critical or unusual situations. These simulations reduce risks to the worker and of equipment damage in dangerous procedures [5]. The incorporation of virtual reality into Serious Games encompasses three fundamental principles: (i) the interaction, which related to the ability of the virtual environment to respond to user actions, (ii) the involvement, referring to the permanence of the user's attention so that the multi-sensory experience both attracts and motivates the users to learn (iii) the immersion can provide the user with the sensation of presence in the simulated environment [6] [7].

User interaction, whether in relation to the scene elements, such as objects and other characters, or in relation to instructions of action, can be automated through the use of artificial intelligence, which can, for example, manage the behavior of characters not controlled by the player (Non-Player Characters, or NPCs), the process of decision making based in players behaviour and the evaluation of their performance, classifying the level of knowledge of the players on the subject [8]. Different AI techniques can be used in serious games depending on their function and the complexity of the proposed problem.

This article aims to present the state of a research that aims to establish a method to verify the user's security conditions during the provisional by-pass installation activity in a virtual energy substation developed in *Unreal Engine 4®*. The proposed method to detect user violations in relation to safety distances is based on an Artificial

Neural Network(ANN). The following is a brief survey of some artificial intelligence techniques used in Serious Games, a description of the virtual environment modelled on Unreal and the temporary by-pass installation maneuver, the modelling of the problem of security distance, which is a violation that may be performed by the user and a solution to the problem through the use of an Artificial Neural Network is proposed.

## II. ARTIFICIAL INTELLIGENCE APPLIED TO SERIOUS GAMES

Finite State Machines (FSM), despite the fact that they do not fit exactly into intelligent systems, are widely used in computer games. They can simply be reproduced by a graph, in which the nodes represent the decisions to be taken and the arcs the possible state transitions. The main disadvantages of using FSM, is that its states are finite, therefore, the behavior becomes repetitive and predictable and when the quantity of possible states increases, the larger the associated graph, which makes this model have an exponential complexity and time-consuming process, preventing execution in real time, a fundamental trait for a NPC.

FSM, thus, are for simple problems that require little processing power, adding an ease of understanding, debugging and implementation. An example of the use of FSM is in the serious game "Uma Aventura na Floresta da Dentolândia" [9], in which the FSM controls actions and events based on the player decision making [7].

Fuzzy Logic is a logic that supports approximate modes of reasoning rather than exact ones in order to determine the intensity of a level of pertinence. Therefore, its most common use is in decision making based on inaccurate data [10]. An example of the use of Fuzzy Logic is the evaluation of the user in the gynecological examination simulator [11].

Rule-Based Systems (RBS) consists of a set of statements made by a specialist, which form a "working memory", and a set of rules to replicate these statements. It is an "if, then" system that can be adapted to different cases. For a good performance, it must have a relevant set of statements acting together with rule groupings which encompasses every possible action and the condition that establish if the solution was found or not. One of the most common activities is in team training, as in mStreeT [12], in which it controls NPCs, evaluates player performance and analyzes player's behavior to control the environment [7].

Neural Networks are computational system based on the human neurological system. These systems are composed of connected neurons and weight associated with connections between these neurons. These networks are designed according to predetermined architectures, in which it may have an input layer, one or more hidden layers and an output layer. Internal to each neuron, there is an activation function that will determine the output inside a given range for each neuron. The most used activation functions are the

sigmoid, hyperbolic, linear and step. The Neural Network must be trained, therefore, it is kept in the learning state until weights stabilize and an average square error converges to a minimum value [13]. An example of application is the decision support system and diagnosis of osteoarthritis [14].

A Bayesian Network (BN) is defined by a graph in which every node represents the variables of a given domain, and the arcs relationships of cause and consequence between these variables. Associated to these graphs, there is a distribution of conditional probabilities of each node relative to their parents, which is calculated from the preliminary probabilities [15]. The Bayesian Network is a good approach to dealing with problems that address uncertainties, in which the conclusions can't be reached only with prior knowledge about the problem [16]. An example is the network built for the application in the diagnosis of heart diseases [15].

A Genetic Algorithm (GA) is an evolutionary computation algorithm inspired in the Darwinian theory of natural selection. This concept revolves around the idea of maintaining a population of individuals (also known as chromosomes), wherein all is a candidate solution to the problem. All individuals are tested and evaluated in the problem solving capacity of each generation by an evaluation function. Those that are better evaluated have better chances of reproduction. In the reproduction phase, pairs of individuals are mixed (*crossover*) and/or each may have only a small part altered with small random changes (*mutation*), aiming to achieve a genetic improvement [17]. This algorithm is commonly used in applications of machine learning, in applications with player adaptation needs and in prediction tasks [7]. An example is the model to aid in the diagnosis of ischemic heart disease [7], GAC-Brasil [18].

## III. THE VIRTUAL TEST ENVIRONMENT

### A. Virtual Power Substation

The virtual substation was modelled in *Unreal Engine 4* by the development team. The choice of *Unreal Engine* took into account some factors, namely: *Unreal Engine* is free for research purposes; it was judged that the graphic quality and VR integration were better in *Unreal* comparing with other game engines; and *Unreal* is Open Source.

The virtual environment shown in figure 1 was created to be as faithful as possible to reality in order to ensure that trainees (which are already used to real substations) feel as immersed as possible.

To achieve this objective, a substation model that represented the "average substation" was chosen, that is an installation that shared the greatest amount of similarities with other facilities. Chosen the plant to be used as a scenario, we performed the three-dimensional laser scanning of the environment *in loco*.

The point clouds obtained from this process underwent manual treatment, in which the structures were modeled in a specific software. The same procedure was performed in

each individual component. Hence, it was possible to create a complete environment without sacrificing modularity; allowing the elements of the scenario to be reused in other environments in the future.

The tools that the trainee can use during the training activities underwent similar treatment. With the use of a *3D scanner*, we acquired the basic forms of real objects and, posteriorly, were manually handled to optimize the models, added details and added textures.



Figure 1. Virtual Substation Designed in *Unreal Engine 4*

### B. Temporary by-pass installation by distance method in an electric power substation

The electrical by-pass switch, shown in the figure 2, is a disconnecting switch installed generally in the same structure as the equipment, intended to enable the continuity of the power supply when there is a withdrawal of operation. In the distance method, in an electric power substation, the installation of the equipment consists of 5 preparatory steps, in addition to the standard security procedure common to all activities, as a verification of the dielectric conditions of the tools used and weather conditions [19]. Firstly an analysis of the conditions of the connection and the conductor is done. Then, the conductor is insured with the support of a conductor manipulator clamp and a universal stick, and the attachment points of the *by-pass* are brushed with a steel brush (manipulated with the help of a universal stick). Right after, with a clean rope, dry and electrically tested, measure the length of the *by-pass* to be used, and it's assembled according to this measure. So, the *by-pass* is carefully suspended with the support of maneuver sticks, at the torsion clips eye. Only after these procedures, the installation of the *by-pass* is made [20].

## IV. METHODS AND RESULTS

The data to be collected for ANN training are: (i) the position, (ii) user hand speed, (iii) the distance between the hand and the power cable, (iv) the height of the hands relative to the floor and (v) the humidity of the environment.

The position and speed of the hands are obtained through the basic functions of *Unreal*: "*GetPosition*" e "*GetVelocity*". These functions return the position and speed, respectively, on the X, Y e Z axis. In this manner, the height of the hands is also obtained, by the variation on the Z axis. In order to

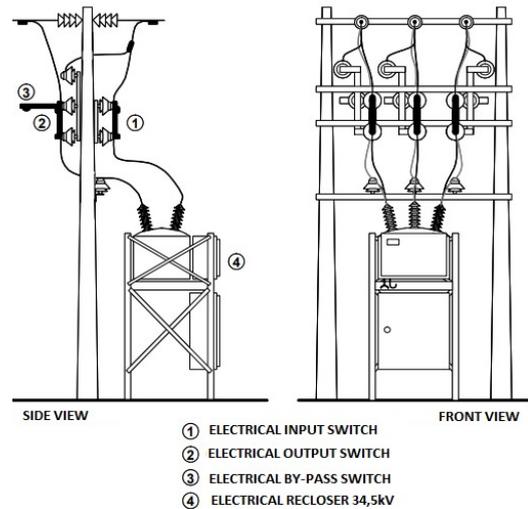


Figure 2. Electrical *By-pass* switch disconnect [20].

obtain the distance between the hand and the cable, two *triggerbox* components will be implemented. A larger one, which starts at the maximum height which the trainee's hand can reach, up to a critical height. From this critical height there is another *triggerbox*, of a smaller size, which extends to the cable. When the trainee reaches the *triggerbox* of the maximum height, a danger warning appears. However, if the hand touches the critical height *triggerbox*, the game ends with a message detailing why the player has failed, because of the risk implied. The *triggerbox* stays invisible to the trainee, contributing only for the game logic and the number of hits for an entry of ANN, but the main purpose is to give trainees the notion of the maximum height which they can reach with their hands. These collected data will be fed into an artificial neural network developed in C++ and *Blueprints* in *Unreal Engine*. Initially, the activation function to be used is the sigmoid, having only a hidden layer. At first, this Neural Network, which was tested out of the *Engine*, is responsible for player evaluation and NPC control. The player's evaluation will be done by means of a score, by the analysis of repetition of errors in the same task, either in a dangerous situation where the player exceeds a safe distance, or if the humidity level is out of the safety standards.

## V. DISCUSSION AND CONCLUSION

Technology evolution has allowed for the use of new approaches in the teaching-learning process. This paper describes the application of artificial neural networks to risk assessment in a serious game designed for training critical activities. Results obtained so far show that this approach can aid in the process of detecting danger in the virtual environment, in this case, based on the distance of electrical components, which is one of the criteria used to evaluate the learning achieved by the trainee.

The AI technique provides efficiency in the acquisition of metrics in Unreal/VR. The chosen metrics can be used to evaluate the performance of the trainee. The procedure of choosing metrics can be improved to obtain a larger and more adequate set of metrics and therefore a deeper analysis of the learning process.

The validation of this system will hopefully prove that the binomial learning-playing can be a serious activity, providing benefits to professionals of critical activities and, in general, providing experiences to players which go beyond simple fun.

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