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Integration of Virtual Labs into Science E-learning

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Abstract

Students can obtain lab content information equally well from two types of laboratories: a virtual and a physical lab. There is great potential in applying a 3D virtual lab based games to support teaching and learning in science. Moreover, it is significant to find practical ways to design and develop intelligent systems based on 3D games with limited complexity forms. 3D virtual environments provide an immersion into the learning contents, and interactions within the virtual world of the game, which are governed by established scientific principles. Therefore, people are looking for the forms of computer simulation - training that require fewer organizational and logistic efforts. Among them, three-dimension virtual environment is the important part of this system in enhancing the learning process. This paper aims to design and implement 3D virtual labs, which are considered as a low-cost alternative to educators and students, in science E-learning. This study focuses on the virtual assembly of instruments, the realization of dynamic 3D gauges, and the setup of emulation-based systems, which are key factors to provide students with the high-immersion 3D virtual lab. It also describes the setup of the network environment of this virtual lab; in this network, the server controls the options, user operations and the processes of experiments. Finally, this research involves designing and deploying a complex application that combines advanced visualization, interactive management through complex virtual devices and intelligent components.

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Keywords: Virtual instrument assembly; virtual laboratory; science; e-learning

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1. Introduction

It is highly desirable that the science theory in middle school be connected to the real world. The scientific experiments are considered as the important methods and processes to understand the scientific phenomena and further investigate the scientific principles underneath. The experiments that the students carry out in real laboratories play significant roles in teaching and learning. Virtual laboratories, as a low-cost alternative solution of real labs, are gaining more and more attentions in e-learning [1].

Myneni, et al. [2] designed a simulation platform ViPS for the learning of physics concepts in the middle-school. Through the virtual setup of the pulley system, the user can simulate the corresponding learning problems.

In our former studies [3], we developed a virtual 3D game environment GISTS for the intelligent tutoring of algebra physics problem. Through this platform, the user can learn and understand the physics theories via an attracting and intuitive form. As a systematical learning environment, theory and practice are both important. Therefore, we consider integrating a virtual laboratory into GISTS.

In the Ecuadorian context there are some initiatives in schools and colleges in the creation of virtual laboratories, for example, in Unidad Educativa Señora del Cisne [4] there is a virtual physics laboratory where children of first semester the school year may enhance exercise of academic activities. Similarly, different schools in the country are equipped with modern computer labs that support learning and enhance the improvement of educational competitiveness. In higher education there are some experiences [5] that describe building a virtual laboratory with intelligent tutor to support the learning of concepts and programming of mobile robots. This laboratory allows simulation of a mobile robot for definition, implementation and execution of path planning practices.

We need many kinds of scientific instruments for the science teaching and learning in middle schools. For an example in the physics experiment, we need the simple one such as ruler to measure the length, and the complex one such as balance scale to weigh an object. The full understanding of the structure of an instrument is an important prerequisite that makes sure students correctly complete the corresponding experiment. Virtual assembly (VA), as a well-known computer-based simulation technology in the engineering fields, is usually employed to collect information about a product, and further to improve or change its design [6]. At the same time, VA is also used in the training field to teach the learners the product's structures and operations [7].

Considering above, we think that an ideal virtual laboratory for E-learning should have the functionalities to simulate the assembly and disassembly processes of instruments. In this research we present our findings on the construction of a virtual laboratory called "science game- based intelligent tutoring" (GISTS). The virtual laboratory provides following tool modules: instrument manual and auto assembly, assembly animation for teaching, and simulation, through which the user can design and setup his/her experiment, simulate the experimental processes, and obtain the corresponding experimental data.

The structure of this paper is: Section II informs about the assembly modeling, which is a sequence that determines the existing parts that can be currently operated. Section III emphasizes the design module that allows creating all categories of 3D virtual gauges. Section IV is the simulation module that provides the basic structure and architecture of an experimental instrument. Section V explains about the network module, which can be managed by a teacher. Section VI provides an example to introduce the implementation of virtual laboratory experiments and a discussion about the topic. Section VII refers to the conclusions.

2. Assembly Modeling

Before the assembly process, we need to prepare the parts of the instrument system. The difference with the models used in engineering field, where the full format CAD models are used, each 3D model in e-learning is prepared with the game static models, which means that there is not constraint information in these models, this because the flexibility and rendering it offers. Hence, the assembly modeling for e-learning can be different from those used in engineering field. Assembly constraint is a kind of important information in VA. All parts are located according to their constraints. A constraint in our system is expressed with two matrixes, the first is the constraint adjacency matrix (CAM) and the second is the position-attitude matrix (PAM).

2.1. Assembly Sequence Planning

Considering the instruments used in the middle school are not very complex, and each one usually contains no more than 20 parts. So for the planning of assembly sequence, constraint adjacency matrix [7-8] is used as an auxiliary judgment, shown in equation (1).

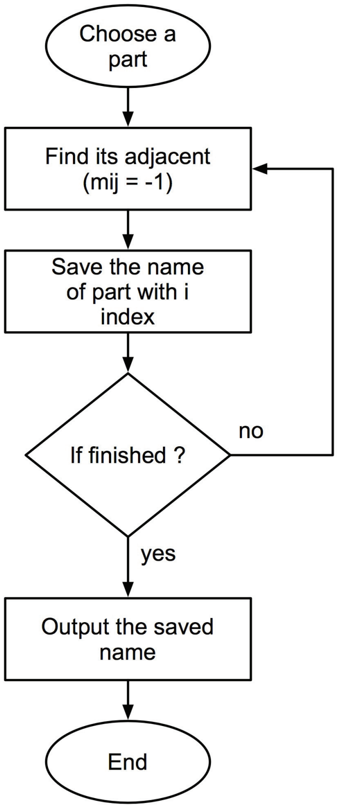


Fig. 1 Flow to determine the current part

The assembly sequence determines the current parts that can be currently operated on. Typically a student would start with a base part (the largest component into which most others fit), and then add other components to the base part step by step based on an assembly sequence. In the assembly process, there may be more than one current part. When a part is chosen, an iterative process is carried out to adjust whether it is the current part, see Fig. 1.

The algorithm for the assembly sequence planning is embedded into the manual assembly process shown in Fig.2. When a student learns to assembly, he drags and moves the current part. Once the current part collides with another, and they are not in the subassembly group, an information hint will pop to warn that these two parts cannot assembly together.

If these two colliding parts are in the subgroup, then the student is guided to adjust the position and attitude of the part. A threshold value is set to indicate if the part is ready to mate. If the relative position of the part is smaller than this threshold value, the part is displayed in bright color. At this step, the system automatically adjusts the position and attitude of the part, and then finishes with the assembly process for this part.

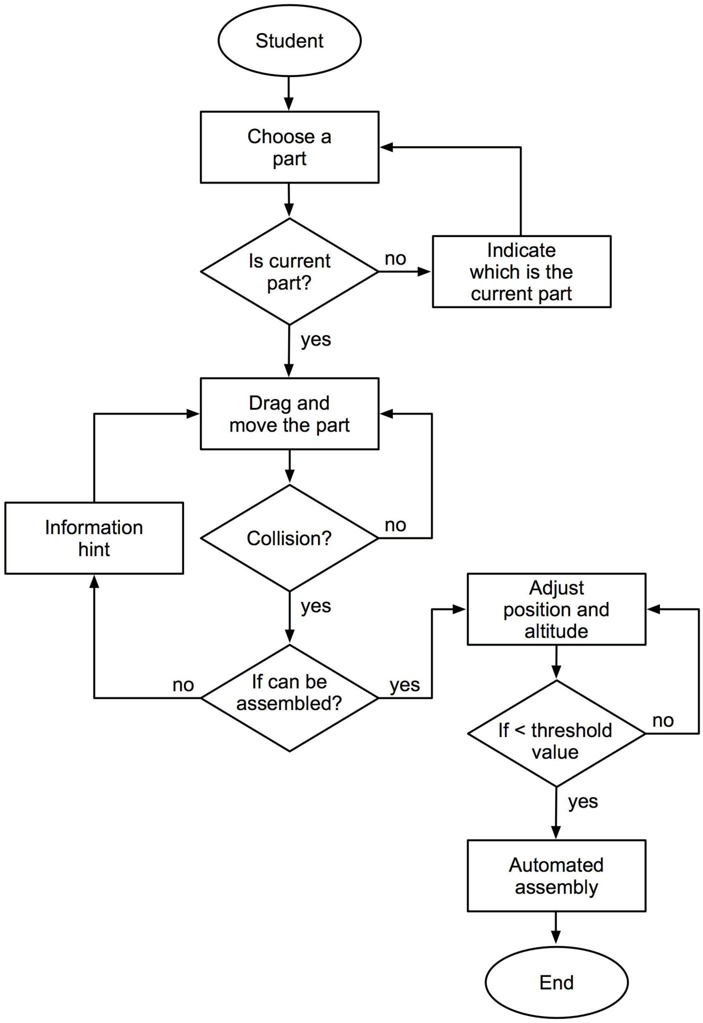


Fig. 2 Flow of manual virtual assembly

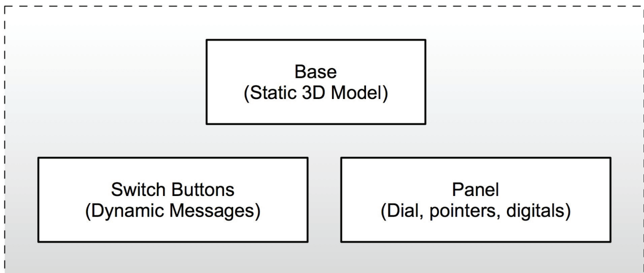


Fig. 3 The structures of a 3D gauge in GISTS

$$M=\begin{pmatrix} 0 & \cdots & 1 \\ \vdots & \ddots & \vdots \\ -1 & \cdots & 0 \end{pmatrix} \tag{1}$$

$$m_{ij}=\begin{cases} 1 & a_i \text{ adjacent to } a_j\text{, and } a_i \text{ should assemblyed before } a_j; \\ 0 & a_i \text{ is not adjacent to } a_j; \\ 1 & a_i \text{ adjacent to } a_j\text{, and } a_i \text{ should assemblyed before } a_j; \end{cases}$$

2.2. Assembly Path Planning

Assembly path is the motion trajectory of parts in the virtual assembly environment, with the purpose for more fast and effective assembly. In virtual 3D environment, assembly path means the series points or curve from starting in position-attitude matrix (PAM) and end PAM. For the manual assembly, the student drags and moves a part, and avoids the obstacles through the collision detection. When he finishes with the assembly process, an assembly path is naturally generated. This assembly path is recorded into an animation file during the assembly process, and will be used to reproduce the operation steps.

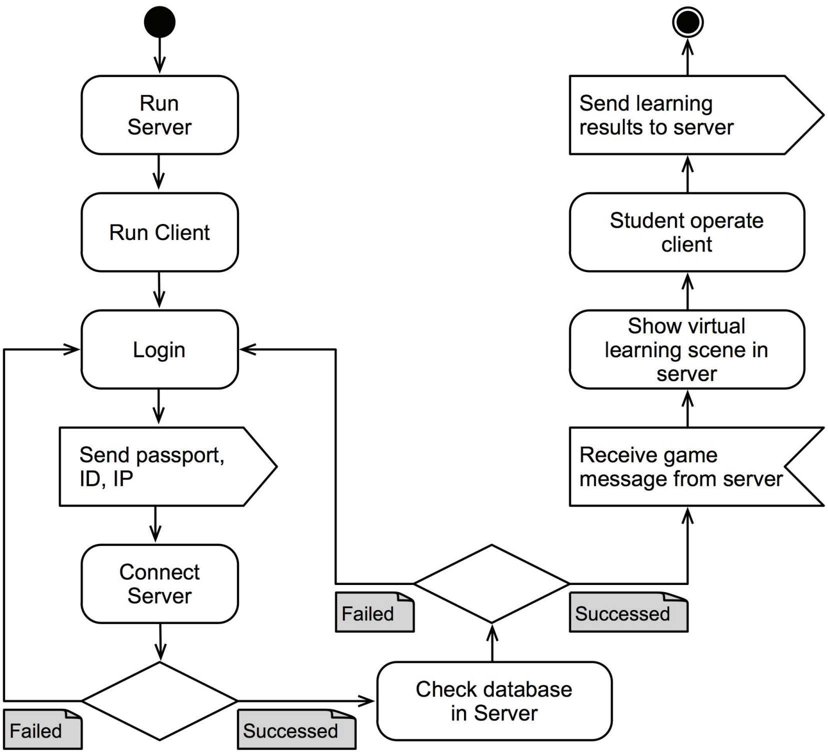


Fig. 4 Activity Diagram of Network in GISTS

This is very important to realize the learning evaluation. Besides this animation file created by the student, the system has another used to automated assembly or assembly simulation. The student can choose automatic assembly to watch the assembly process and learn the basic knowledge about this experimental instrument.

3. Gauge Modeling

The exiting virtual experiment systems are in 2D forms [9], this 2D interfaces make it less attractive and less popular with young students. In real labs, we need various gauges to measure and collect different physics quantities, such as length, time, force, electric frequency, electric voltage, etc. The gauge module in GISTS is designed to create all categories of 3D virtual gauges. Each 3D Gauge in GISTS usually consists of three parts, see Fig. 3. One is the base, which usually is created by the 3D model designer. The second is the panel. Each gauge layer is designed to simulate a dynamic data source. The third is message controller that is consisted of buttons. These buttons are simulated by actors which can emit and receive messages

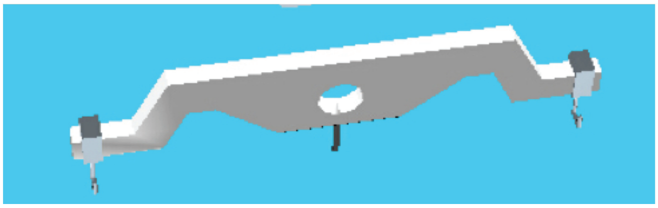


Fig. 5 The special design of 3D beam

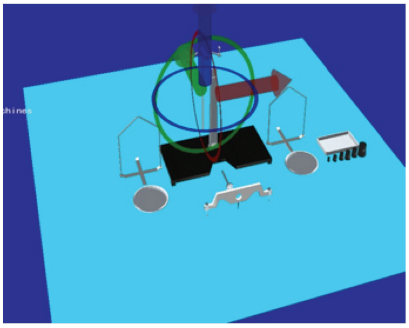
Fig. 6. A 3D Ammeter

4. Simulation Module

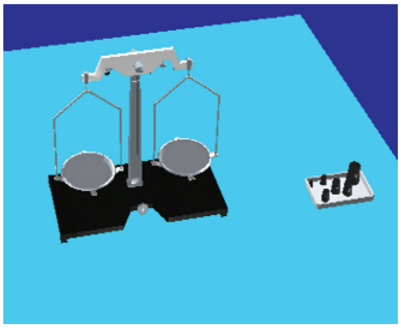
The difference with VA in engineering field where the purpose is to train and improve the assembly skills, VA used in the E-learning is just to help students in understanding the basic structures and architectures of an experimental instrument, and finally help students operate this instrument to simulate the scientific process. The simulation module in GISTS is responsible for simulating the setups created by a learner.

5. Network Module

With the development of network technology, many networked virtual learning system are used, but mainly in military and industry applications. But so far, most networked learning systems are based on 2D virtual instruments, and the 2D instruments in these are only used for statically displaying, not for dynamically simulation. The virtual lab in GISTS is built on a local area network (LAN) environment, see Fig. 4. The server, which can be managed by a teacher, monitors the choices and operations of users and controls the processes of experiments.



(a)



(b)

Fig. 7 Virtual assembly in GISTS (a) manually operation; (b) assembly result

6. Implementation and Discussion

In this section, we use the balance scale as an example to introduce the implementation of virtual laboratory experiments. The balance scale is one of the precision instruments used in the middle-school physics. The goal of the corresponding experiment is to learn how to use a balance scale to measure the weight of an object. The existing virtual laboratories developed for young students are commonly based on flash technologies [10]. There are some advantages in attracting students for these systems, but they cannot completely the real physics processes. Considering this, we employ the dynamics engine Open Dynamics Engine (ODE) to simulate the dynamics in the operation process of balance scale.

Because of the sensitivity of the balance to the force, it is not easy for the beginner students to control and operate the balance scale. Just for the same reason, as the designers, we must be very careful in controlling the touching joints of ODE in the balance scale. For example, when designing the 3D model of the beam of the balance scale, we must set a proper value for the thickness of the beam, see Fig. 5. If this beam is of the same thickness as the real one, the simulation will be unstable

Fig. 6 shows a 3D ammeter. As instructed in Section 2, each 3D Gauge has a panel. Currently, the panel is designed and developed by OSG gauge layers. In the case in Fig. 6, the panel is covered with two OSG layers. The Dial is the base layer, which is static, and the second layer is the pointer, which is dynamic and designed to simulate the running state of a gauge. The game actors design the buttons in the ammeter.

The correct collision response can simulate the real operation process. The collision detections in virtual assembly of GISTS are realized by a special motion mode. When this mode is active, the parts in the virtual laboratory can collide with others. And this motion mode was developed in such a way we can move a part in three different modes i.e. move, rotate and scale, see Fig. 7a.

This feature was crucial as it allows for a more precise placement and alignment of 3D objects in the work space of GISTS. During the process of dragging operation, the constraint relations between the parts are limited by setting of the collision detection and collision response. Fig. 7b displays the assembly results. The dynamics simulation is realized by ODE in Delta3D.

In order to achieve training evaluation for the assembly process, the PAM of a selected part is recorded within given period time. Therefore, after finishing the manual assembly, the assembly process can be displayed in a video form.

7. Conclusion

On the one hand, the existing virtual laboratories for science learning in middle school need to be improved because of several issues, such as 2D form of the learning environment, weak attractiveness to the young students, and weak reality of the experiments. On the other hand, the virtual laboratories with high-quality realistic 3D graphics and a high level of interactivity are only widely used in military or industry training. In order to construct high-level virtual laboratories for middle-school science learnings, this study presented to improve the virtual laboratories from two points: (1) integrating the industry-used assembly technology into the virtual laboratory experiments; (2) introducing 3D gauges into the virtual laboratories. These two points can greatly enhance the reality and attractiveness of the virtual laboratory experiments, so that its experimental assignments will not only help students to better understand scientific processes and rules, but also teach them how to apply the acquired knowledge to practice.

The future work lies in two aspects. One is to systematically implement various experimental learning contents. Another is to improve the network module to develop a virtual campus-based virtual laboratory system.

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