Adventure-Style Game-Based Learning for a Biology Lab

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ABSTRACT

Universities and medical companies face constantly the challenge of developing protective or adaptive countermeasures for the purpose of training new students and employees in the use of their laboratories and the assimilation of complex experimental methods. Yet the existing space and time limitations along with the high cost and sensitivity of some laboratory instruments, which are therefore not fully exposed to manipulation, result to a stiff and not always successful training procedure. The proposal deals with this problem by the creation of a game-like interactive simulation environment for the trainee to be trained in the absence of risks of undesirable consequences. The developed test-bed application is an interactive virtual environment simulating the biology laboratory at the Hellenic Open University. In this, the trainee acts by interacting with the laboratory equipment and light microscopes. By using such an application, the trainee is allowed to cause an unlimited number of unintended experimental tests and learn by "trial-and-error".

Categories and Subject Descriptors

K.3.1 [**COMPUTERS AND EDUCATION**]: Computer Uses in Education – *distance learning*.
J.3 [**LIFE AND MEDICAL SCIENCES**]: *biology and genetics*.
K.8 [**PERSONAL COMPUTING**]: *Games*.
D.1.6 [**SOFTWARE**]: Logic Programming.

General Terms

Design, Performance.

Keywords

Educational Games, Adventure Games, Virtual Worlds, Biology Laboratory, Logic Programming.

1. INTRODUCTION

Science universities and medical companies deal constantly with the problem of teaching new incoming students and laboratory employees how to make proper use of lab equipment and how to safely carry out experiments. In most cases, the laboratory equipment is sensitive as well as expensive; therefore, it is not affordable for trainees to have the opportunity to make improper use and learn by "trial-and-error". The problem is aggravated when the number of trainees is large and their training takes place simultaneously at the same lab, where not only are they prone to cause damages and accidents but, also, the learning process is heavily compromised. Thus, a computer game providing with an interactive simulation environment of the lab in which the trainee is allowed to experiment and make as many mistakes as they wish in order to learn (the reproduction of an animation with the damage caused when an improper action is taken serves this purpose), where no time or space limitations are imposed on them, would definitely preserve and enhance performance and safety in the evolving trainees.

Our work simulates an interactive virtual environment to allow for virtual experimentation in the biology laboratory at the Hellenic Open University. Therein, a human agent (user) interacts with the laboratory instruments in a number of modes. The goal is to guide the human agent in hands-on learning how to make appropriate (and safe) use of the equipment and how to successfully carry out experiments.

2. IMMERSIVE LABORATORY EDUCATION

The biology laboratory at the Hellenic Open University is responsible for providing undergraduate students with practical training in biology; that involves manipulating the laboratory equipment, conducting safe experiments and observing samples with the microscope. However, most students encounter major difficulties in their attempt to get full understanding of the different laboratory instruments and experimental procedures due to the time constraints and safety rules on the training process.

2.1 A Brief Overview of the Application Domain: Biology Laboratory Safety

Biology training laboratories are challenged by the simultaneous practical training of many trainees, who often have no previous experience in laboratory environments. Since the cost of the laboratory instruments, replacement parts and consumables is quite high, also depending on their quality and versatility, academic programs offer to their students a set of laboratory safety courses, prior to real lab practice, so as to minimise the risk of causing damages to laboratory equipment and inflicting serious human injuries or contracting infections. Biological safety regulations apply to all different experimental procedures performed in a biology laboratory and, generally speaking, involve safety rules for biological materials, which are potentially infectious (use of animal or human tissue/body fluids, bacterial and eukaryotic cell cultures), as well as safety rules concerning the proper use of the laboratory equipment [1].

2.2 Biology Laboratories as Virtual Environments

Taking all those limitations into consideration, we took the initiative to implement a virtual laboratory environment for the Hellenic Open University students to be trained in.

Learning a subject by interacting through a virtual class is admittedly more efficient than attending a lecture or reading books on that. While reading helps a student to assimilate a subject by 10% and lectures by an even lower rate, the respective percentage for practice doing (in which interacting through a virtual world is included) is 75%. Furthermore, virtual classes provide shy or restrained students with the opportunity to perform learning actions such as asking questions, that they would probably be reluctant to do in a real class [2].

Interactive computer-based applications for science and biology learning has in the past been developed and tested among students and claimed encouraging learning results; 212 junior high school students (13-14 years old) students in Greece were provided with an interactive 3D animation, accompanied by narration and text, dealing with "methods of separation of mixtures" which in general, did increase the students' interest in science [3], while 44 magnet science and medical technology high school (17-18 years old) students in Texas, USA improved their molecular biology skills by using a computer-based simulation designed for training in the production of a transgenic mouse model, independently of their previous knowledge of it [4]. Moreover, a virtual world under the name of Multiplayer Educational Gaming Application (MEGA) was designed for and used by 131 US college prep students in which the latter had to solve a CSI-like murder case using their skills of scientific inquiry such as understanding of pedigrees and Mendelian inheritance; eventually, 94% of the participant students successfully practiced their basic scientific skills to solve the case [5].

3. MODELING OF EDUCATIONAL INTERACTIONS

The educational design of the application is based on the diagrammatic representation of every procedure that the agent has to follow in order to successfully conduct an experiment or make any other use of the laboratory equipment. The task that the agent has to accomplish in order to carry out a learning process is simply to find their way to the goal state starting from a beginning state and passing through a graph of several intermediate ones.

3.1 The Application's Environment

The virtual laboratory environment we are dealing with is discrete, meaning that there are a finite number of distinct states for the agent to be at as well as a specific set of action for them to make. Furthermore, it is deterministic, meaning that the next state that the agent will be is completely determined by the current state and the action executed by the agent [6].

3.2 States, Features and Actions

The various entities in this environment, both objects and the agent, have some features, each of which is each time at a specific state. Each object has some specific *singular actions* that the agent can performed exclusively on it (thereby called singular); such are *look*, which returns a description of the object under observation, *examine*, which returns a more thorough description of it, *use_1* – also known as *singular use* (not just action) which corresponds to the object's exclusive use. Furthermore, there are the *joint actions*, *use_2*, which concern the *joint use* of two objects. After every singular or joint action on one or two objects respectively, it is possible that a state change of any of its or their features takes place, or the agent's features as well.

3.3 Classes and Instances

One or more kindred entities belong to a class, while each entity of this category is represented by an instance of that class. All laboratory objects as well as all microscope parts are instances of specific classes; the agent is an instance of the special *ego* class which represents the human agents involved in the game.

3.4 State-Transition Diagrams (STDs)

The different states and the changes from one another concerning an entity's feature are represented by a state-transition diagram (STD). In general, STDs are a powerful tool for abstracting changes in time-dependent systems, but their use can be extended to include the representation of changes of non-time-critical systems as well [7].

An STD concerning the change of the feature *tidiness* of *concoction* class, representing the concoctions to be observed with the microscope, is depicted in figure 1.

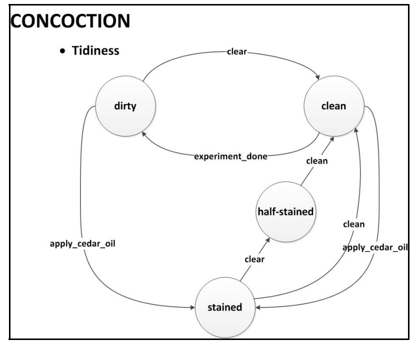

Figure 1. Paper's *state* feature's STD.

Each transition from one state to another is perpetrated by an action (singular or joint) performed on this entity (less often it is triggered externally). For example, in the diagram above the transition *clear*, which changes the state of a *concoction* instance from *dirty* to *clean*, represents the joint action on the *concoction* and a *cleaning_wipe* instances, because the *cleaning_wipe* class has a feature that is common for all its instances, namely *function*, which has the value of *clear*.

Based on that design, we have created 23 classes, each one of them representing a mechanical part of the microscope or a category of kindred objects in the lab, and 19 STDs concerning various features of those classes.

Last, but not least, comes the diagram for the *state* feature of the agent or, in other worlds, the *trainee* instance of the *ego* class.

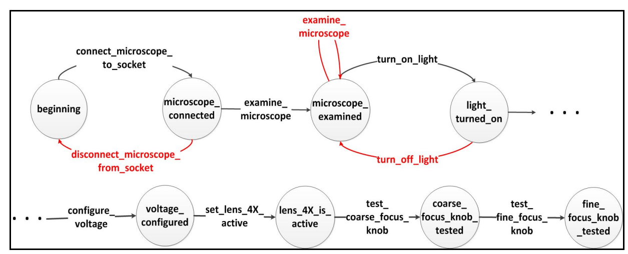

Figure 2. Trainee's *state* feature's SDT.

For example, the procedure of getting acquainted with the microscope which consists of several steps such as plugging it into the socket, thoroughly examining its various parts, turning its light on, adjusting the latter's voltage etc., would correspond to the STD for the *trainee*'s *state* feature depicted in figure 2. Complying with the hierarchical agent architecture [8], we use two different *layers* for our STDs; the *trainee*'s *state* STD stands at the top level layer while the ones of the other entities' features exist at the bottom level one.

4. IMPLEMENTATION ASPECTS

The application's implementation is two-fold. At first, a text-based kernel in SWI-Prolog is implemented, where the actions to be taken are instructed in the language's listener, and which serves the purpose of a flexible test-bed platform; thereafter, a fully realistic adventure game is being developed in a high-end 3D platform, where the agent's actions are triggered just by the player with the use of the mouse.

Due to its declarative nature, Prolog renders itself a perfect tool for the exact simulation of the discrete laboratory environment, given the detailed STD-based specification (see section 3).

The interaction between the user and the application is made through SWI-Prolog's text interface. Specifically, the user provides Prolog's listener with text commands corresponding to the permitted actions and received text feedback as confirmation that an action indeed succeeded or failed and what changes considering the various features' states it resulted in.

Our 3D game application has been implemented under Hive3D game engine.

In order to provide both realism and user-friendliness, the interface between the human agent (user) and the environment has been developed in a way that it resembles the one of a modern commercial 3D Adventure Game; the user uses the arrow keys to navigate in the lab while they use the mouse to press buttons, turn knobs, use specific objects alone or in pairs and collect several of them in their inventory.

A representative screenshot of our 3D game is depicted in figure 3.

Figure 3. Graphical design of the biology laboratory's microscope and equipment at the Hellenic Open University.

5. EVALUATION

The 3D Game Application was evaluated by 19 biology students, aged from 35 to 50; all of them consisted of the same class, that is, they were all conducting their activities in the lab, both simultaneously and in private.

The evaluation was a qualitative research with the group of biology students being the sample. The qualitative approach in regard of the data collection and the elaboration of the results was considered to be the most appropriate as it focuses on the attitudes and the beliefs of the research subject themselves [9]. For the collection of the qualitative research data, the focus groups technique was selected and the System Usability Questionnaire (SUS) for systems engineering was employed [10].

The results of the evaluation process were positive; all students found the application easy to use while two of them managed to complete the game before they were even suggested how to do that; both students who had already read the laboratory manual and those who hadn't didn't face any difficulty playing the game while four of them asked if there was a website to download it from in order to use it at home as well.

6. CONCLUSIONS & FUTURE WORK

So far, our delivered work consists of two parts; the theoretical design of the virtual biology laboratory and its two-fold implementation, the text-based kernel and the 3D game application.

Our first future goal is to expand our 3D game so that all laboratory instruments are included in it; our next one is to use the expanded game environment as a test-bed for machine learning applications, that is, computer agents will enter the environment with the purpose of learning not only by interacting with the laboratory equipment but by being instructed by a human agent, too.

7. ACKNOWLEDGMENTS

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