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An Immersive 3D Virtual Learning Environment for Analyzing the Atomic Structure of MEMS-Relevant Materials

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Abstract

In this paper, an immersive three-dimensional (3D) virtual learning environment based on the Oculus head-mounted display is presented for analyzing the atomic structure of monocrystalline materials relevant to Micro-Electro-Mechanical Systems (MEMS), e.g. Silicon (Si), Chromium (Cr), Titanium (Ti) and Copper (Cu). This environment allows the real-time visualization and interactive analysis of key crystal lattice parameters, e.g. number of atoms in the lattice, atomic packing factor, linear atomic density, surface atomic density, volumetric density, etc.

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1. Introduction

The new technological and social vicissitudes of the twenty-first century highlight necessary transformations in education. Preparing students for learning in these rapidly changing settings is a challenge for educational institutions and requires rethinking the methods and objectives of the teaching-learning process. Furthermore, in

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order to be digitally competent these day, teachers and students need to not only transfer and acquire knowledge, but to develop the skills and attitudes that are appropriate to their profession as well as to improve classroom practices by efficiently and effectively using information and communications technology (ICT) ¹.

The possibility of implementing instructional design in a three-dimensional (3D) virtual environment for the learning process enables an immersion into a mixed reality that can be tailored to the evolving and specific requirements of modern learners, enabling them to transition from classroom instruction to the reality of a profession². In this case, the work presents an interactive 3D virtual learning environment based on the Oculus head mounted display³, to analyze the atomic structure of monocrystalline materials relevant to MEMS (Micro-Electro-Mechanical Systems) in order to provide the students highly motivating learning experiences with immersive 3-D spaces.

2. Competency-Based Education in Virtual Environments

A competence is often defined in simple terms as putting knowledge into action. This invariably also encompasses the required skills and attitudes for the successful performance of an action, or of some functions and roles in a given area or for life in general⁴. In this paradigm, the teaching-learning process goes beyond the mere transfer of information to the creation of context-rich situations where students can think, discuss, collaborate and thus learn actively.

The perspective of education on virtual environments involves determining the most appropriate means to match specific learning situations to the characteristics of individuals (e.g. skills and prior knowledge). At the technological level, virtual worlds are based on a client-server model as shown in Figure 1, where each client accesses the server through a graphical browser or interface and get all the graphic data in real time, unlike other game engines in which data is stored locally⁵.

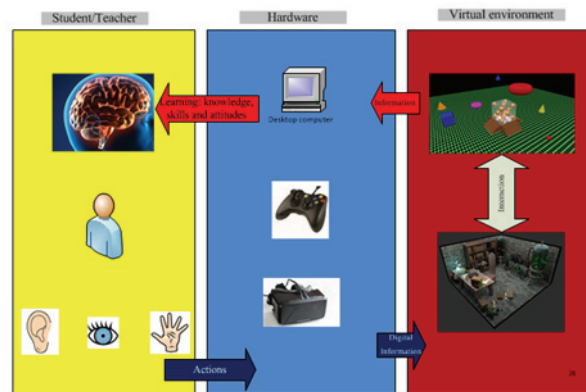


Fig. 1. Human-computer interaction model of the proposed virtual learning environment.

3. MEMS (Micro-Electro-Mechanical Systems)

Micro-Electro-Mechanical Systems (MEMS) is a mature technology for integrating sensors, actuators and control electronics on the same chip, whose industry is preparing to exceed 20 billion USD by 2020 and also have been recently accepted as part of the curriculum of engineering programs.

In this area, the structure analysis of matter is fundamental to understand and control its chemical and physical properties. Modern methods to analyze the atomic/molecular structure of materials include X-ray diffraction, atomic force microscopy, neutron diffraction, electron diffraction, molecular modeling, high and low-temperature studies, high-pressure diffraction and micro-gravity experiments in space⁶. However, from a pedagogical perspective, traditional visualization techniques have been mainly limited to 2D projection images, which are not always appealing to students and do not facilitate depth perception. Recent works on virtual learning environments suggest

that highly accurate perception of an atomic structure is facilitated by the use of immersive environments in which the operator may manipulate and measure important intrinsic information about the structure⁷.

4. Development and 3D design environment

The graphical interface and usability of the proposed model was implemented in the augmented reality helmet Oculus, as shown in Figure 2, where users freely explored the 3D environment and then reviewed and discussed all of its aspects. As a first step for the development of the environment, a storyboard was made, allowing to determine the scenarios and the elements needed to be modeled. In this case, the environment have two scenarios, as shown in Figure 3. In the Laboratory view, users can select and read relevant information on the material to interact within the 3D environment; in the lattice view, users can read instructions and interact in real-time with the atomic structure of the selected material, analyzing key crystal lattice parameters, e.g. number of atoms in the lattice, atomic packing factor, linear atomic density, surface atomic density, volumetric density, etc.

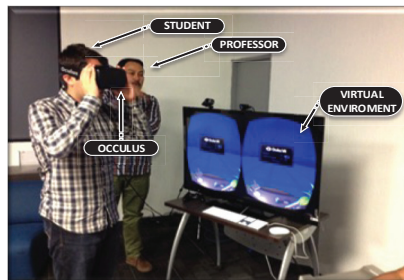


Fig. 2. Users testing the graphical interface of the proposed model.

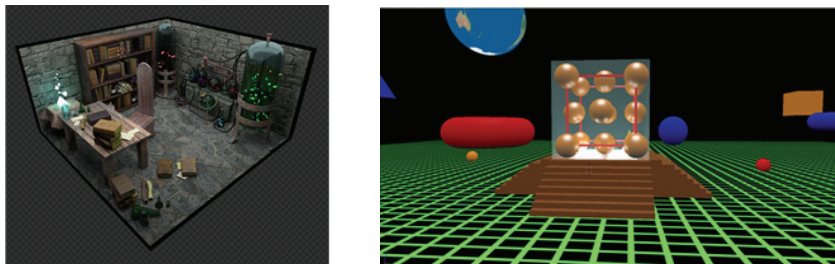


Fig. 3. Scenarios of the proposed model: (left) Laboratory view and (right) Lattice view.

5. Conclusions

This work has shown the design, development and evaluation of a 3D environment for analyzing the atomic structure of matter, which together with suitable teaching strategies, may favor the skills and attitudes acquisition that are appropriate to the profession of university students from the MEMS area.

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