



Simulation of the preparation laboratory for light microscopy in the form of a 3D educational game

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ABSTRACT

Purpose: The purpose of the work was to create an educational game to familiarize the user with the methodology of preparing a material sample for light microscopy. The goal of the game is to obtain a correct preparation of the sample, the microstructure of which can be observed under a light microscope.

Design/methodology/approach: The game was developed in the Unity environment. All three-dimensional machine models, along with the necessary virtual environment and the gameplay scenario, were created.

Findings: Due to the use of virtual reality, it has become possible to teach students how to use preparation devices without the need for the physical presence of students in the laboratory in an attractive and safe way. Failure to play the game will not damage material, or equipment, there is no risk to the user's health.

Practical implications: The game has been developed and is available in the Department of Engineering Materials and Biomaterials of the Faculty of Mechanical Engineering of the Silesian University of Technology.

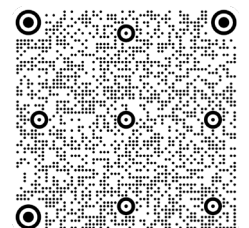
Originality/value: The form of a 3D game used in this study is an interesting alternative to traditional teaching aids. It can be used not only by students but also teachers and other people who want to broaden their knowledge about the functioning and methods of operation of laboratory equipment.

Keywords: Computer aided teaching, Simulation of research equipment, Interactive 3D educational game, Virtual laboratory

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EDUCATION AND RESEARCH TRENDS



1. Introduction

The specificity of knowledge transfer through e-learning systems has necessitated the development and implementation of new virtual tools. Currently, the processes of acquiring knowledge, skills and abilities take place outside school desks and laboratories. They were transferred to virtual reality. Newly developed teaching processes supported by telecommunications technologies necessitated the design and development of a new type of electronic educational materials. A special case of such materials is research equipment simulation programs that simulate the operation of real scientific or laboratory devices used for science, research and educational tasks at technical universities [1-8].

The process of creating simulators is no different from creating other software. Like all programs, they are written almost from scratch using one of the programming languages and the appropriate libraries already created for it. The language is selected depending on the requirements set for the simulator. When creating a machine simulator, the programmer's task is to reproduce the operation of the machine or the phenomena of the simulated equipment as accurately as possible. For this purpose, graphic engines are usually used, thanks to which, using specially created and animated models, the user will be able to interact with a virtual machine, enter data into it, observe the course of the simulated process and receive its result. Models can be created in any program that allows modelling, animation and 3D rendering. It can be both software used by professional graphic designers, such as 3DS Max or Blender, as well as CAD software, mainly used for design, such as AutoCAD or Solidworks [9-16].

In the case of creating simulators, ready-made game engines are often used along with programming environments specially prepared for working with them. They facilitate the development of software by providing the user with a large number of tools and ready-made templates. They also take over a lot of computing activities, relieving the programmer. One of the engines gaining more and more fame in recent times is the Unity engine. Along with the Unity engine, the user also gets access to the Monodevelop script editor. It is an editor that allows you to create scripts in JavaScript, Boo, as well as C#, which is the most popular among programmers dealing with games based on this engine. When creating games using this environment, the Unity graphics engine is used, developed for the environment of the same name, additionally supported by OpenGL and DirectX libraries. The biggest advantage of Unity is undoubtedly its cross-platform functionality.

Games created using this engine run on platforms such as Windows, Linux, Mac OS, Xbox 360, Playstation 3, Wii, Android, and Wii, as well as on mobile platforms. Another advantage of working with the Unity engine is its price. Unity is free software, also allowing commercial use [17-22].

2. Purpose and scope of work

The purpose of the work was to create an educational game to familiarize the user with the methodology of preparing a material sample for light microscopy. The goal of the game is to obtain a properly prepared sample that can be observed under a light microscope. When playing this game, the user has to perform all the steps that would have to be performed in a real laboratory to obtain a suitable sample from a piece of material. The laboratory for sample preparation for light microscopy, equipped with facilities available to the Department of Engineering Materials and Biomaterials of the Faculty of Mechanical Engineering of the Silesian University of Technology, was used as an equipment base.

The scope of work was the creation and programming of three-dimensional machine models with appropriate functionality and interface. Then a so-called scene was created. It is a virtual environment in which these models are to be located. It is also here that the user's work with virtual hardware will take place. The next step was to animate the movements and animations of these machines so that they would reflect the actual operation of the presented devices as much as possible. The last step was to develop the gameplay scenario and allow the user to start the game. All users who are unable to obtain knowledge due to the lack of access to real equipment and have a computer with internet access can play the game and thus use the simulators included in the game.

Before examining material samples under a light microscope, a series of activities must be performed to observe the material's microstructure. These steps are cutting, inclusion, grinding and etching the sample. Taking a sample usually involves cutting it, using a saw or torch, from an element that has been subjected to thermal, chemical, mechanical or other treatment. Inclusion involves embedding the sample in a polymeric material to facilitate storage and further processing of these samples. Grinding the sample is aimed at smoothing the surface to be observed and thereby improving the reflectivity of that sample. Sample etching is aimed at final smoothing of the surface to be observed, impossible to be done by mechanical methods. Only after all these steps have been performed can the

microstructure of the sample material be observed on a light microscope.

Due to the use of virtual reality, it has become possible to teach students how to use preparation devices without the need for the physical presence of students in the laboratory in an attractive and safe way. Failure to play the game will not damage material or equipment. There is no risk of losing the health of the user caused by the unskilful use of the equipment. In case of making a mistake, the player must restart the game and perform the actions again until the correct ending is obtained.

After starting the game, the player has the option to choose the resolution of the game screen. You can choose very low game parameters, which allows you to run the game on very weak and outdated computers. The next parameters are the detail of the displayed graphics and the number of the monitor on which the image should be displayed (available only in the case of multi-monitor systems). The game can be run in a window or full screen mode.

3. The process of creating virtual simulators of preparation devices for the purposes of light microscopy

Machine models were created with Autodesk Inventor with the dimensions and colours as close as possible to realism. Animating the models was possible thanks to the

use of the built-in Unity3d game engine and one of its tools called Mechanism. With its help, animations are created for individual model elements, e.g., by determining the position, rotation or its scale at a given time from the beginning of the sequence in three-dimensional space.

The developed model of the virtual laboratory included the preparation (Fig. 1):

- Discotom-2 cutter,
- Predopress hydro-pneumatic hot mounting press,
- LaboPol-1 grinding and polishing machines with the Struers Laboforce-1 head,
- Olympus SZX9 optical microscope.

Simulators can reproduce only a limited number of processes that a programmer can predict and develop. The simulation will never be able to fully reproduce the functionality of the simulated machine, so when creating such software, it is worth focusing on working conditions, functions and processes, the exact representation of which is especially important for the entire project, to prevent them being overlooked during the software development process. It is worth focusing on a single function that is used by a given device. Most machines allow the process to be carried out in several ways, but rarely are all of them used. In this case, it may be a good idea to simulate only selected functionalities used in a given device. Although this will limit the functionality of the program, it will also allow you to reduce costs, time in which the software is created and more accurately simulate the key function for a given device.

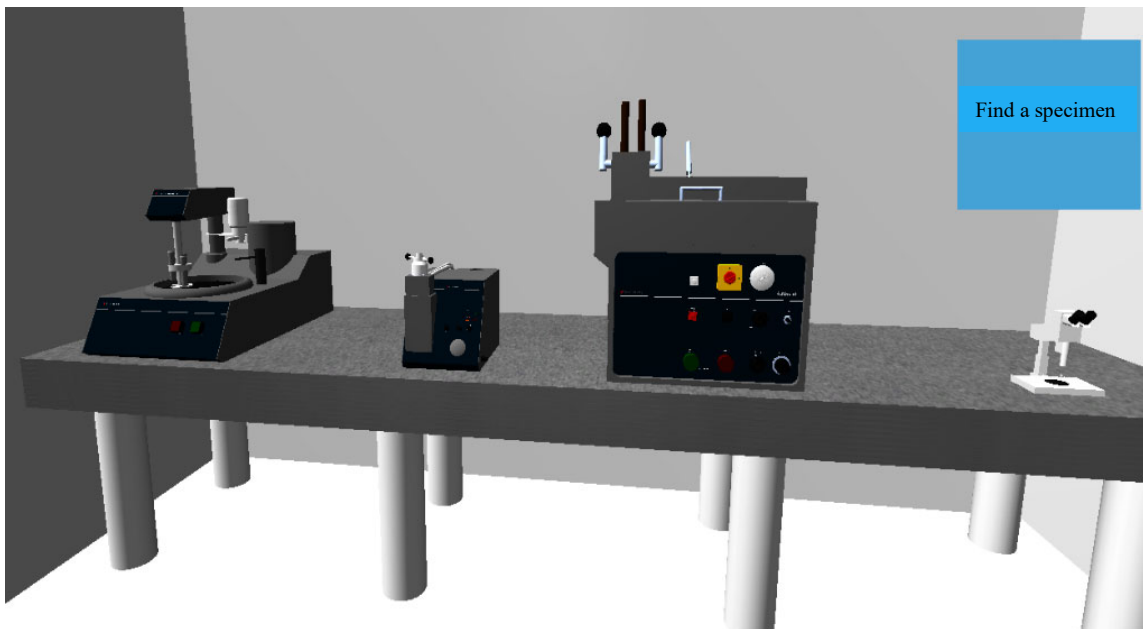


Fig. 1. Simulated virtual laboratory, a) machine for grinding and polishing LaboPol-1, b) hydro-pneumatic press for hot mounting Predopress, c) Discotom-2 cutter, d) Olympus SZX9 microscope

If necessary, the functionality of the simulator can be extended at any time. Incorrect or cursory presentation of an important functionality may cause incorrect understanding by the user of such a simulation and, as a result, poor quality of teaching.

3.1. Simulation of the Discotom-2 laboratory cut-off device

Struers is a world leader in the manufacture of equipment and consumables for the preparation of metal specimens. It was founded in 1875 as a company supplying laboratory equipment. The Discotom-2 cut-off device (Fig. 2) already belongs to a rather vintage series of cutters; however, it is still capable of handling most of the tasks set before it.

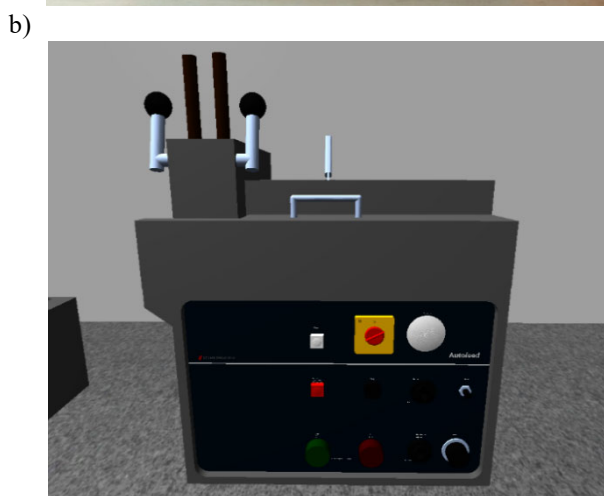


Fig. 2. Real (a) and simulated (b) cut-off device Discotom-2 manufactured by Struers

Its big advantage is an extremely simple operation. The machine is operated using a control panel. In order to be able to start the machine, both the cutting disc cover and the special table on which the sample is mounted must be closed. The cutting process can be carried out in two modes:

- automatic, in which the machine selects the cutting parameters by itself,
- manual, in which the user can set such parameters as the pressure and rotation speed of the cutting disc.

The sample is mounted on a special table with two levers. The sample dimensions should allow it to be placed in the machine without blocking the cutting table cover. During the cutting process, the cutter blade is cooled by a liquid supplied to the blade chamber through a special pipe. The type of disc used in the cutter depends on the material the sample is made of. Hard materials should be cut with a soft disc and vice versa. The simulated process assumes the use of automatic mode. Before commencing cutting, the user should attach the sample and close both covers. The next step is to set the pressure within the proper range, set the Feed/Retract switch to Feed position, and turn on the main switch. The speed of turning the switch should match the speed of normal cutting. When the cut is complete, the blade should be moved back to its original position by setting the Feed/Retract switch to Retract position.

3.2. Simulation of predopress hydropneumatic hot mounting press

The purpose of mounting laboratory samples is to ensure that it can be easily and conveniently mounted during grinding and polishing processes and to avoid rounding the edges of the samples. We distinguish between hot and cold mounting methods.

Hot mounting is characterized by the high quality of products and short production time. It is used when it is often necessary to prepare small amounts of samples. It is necessary to use a mounting press for the production, but the resins used to fix the sample are cheaper than with the cold method. The sample placed in the press is exposed to elevated temperature and high pressure. The resins used are divided into thermosetting resins that harden when heated and thermoplastic ones that soften with increasing temperature and that harden upon cooling. Cold mounting takes longer, even up to several hours, but does not harm the samples sensitive to temperature rise. It also does not require the use of mounting presses. The mounting process consists in placing the sample in the mould, precisely measuring the proportions of the resin and hardener components, mixing thoroughly, pouring the sample into the mould and waiting for the material to harden. Epoxy resins are used, which show

very low shrinkage and allow for very effective or complete reduction of the occurrence of rounding of the sample edge, as well as acrylic resins, which are easy to use. A Predopress machine by Struers was used for hot mounting (Fig. 3).

a)



b)

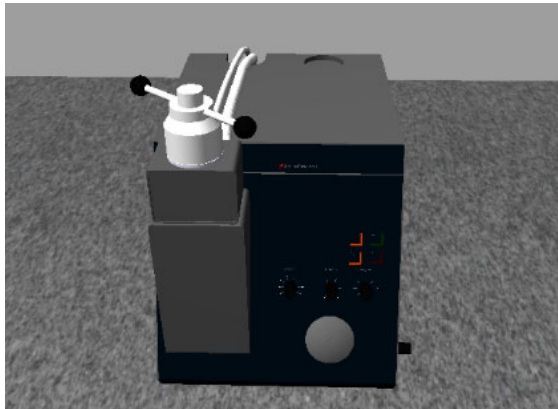


Fig. 3. Real (a) and simulated (b) hydropneumatic hot mounting press predopress manufactured by Struers

3.3. Simulation of grinding and polishing LaboPol - 1 with LaboForce - 1 head

Grinding of metallographic samples is divided into two stages: coarse and fine, which are designed to remove material damaged caused by friction, crushing and high temperature during the previous processing and sampling. The first is made with grinding discs, while the second one uses sandpaper with increasingly smaller abrasive grain sizes. It is changed when the traces of the previous treatment

disappear from the ground surface, and the sample is rotated by 90 degrees. It is necessary to be careful to not cause another damage to the sample, and also to avoid overheating by using wet paper in machines ensuring constant moistening of the ground surface. For this project, we used a model of the Struers Labopol - 1 grinding and polishing device with the LaboForce - 1 head (Fig. 4). The first one is characterized by a constant rotational speed of the disc of 250 revolutions per minute, the second one rotates the column at a speed of 8 revolutions per minute and allows mounting up to 3 samples. They are pressed against the grinding wheel with a constant force of 2 to 20 newtons.

a)



b)

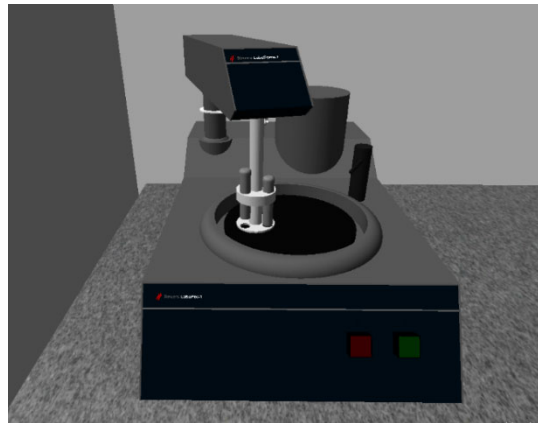
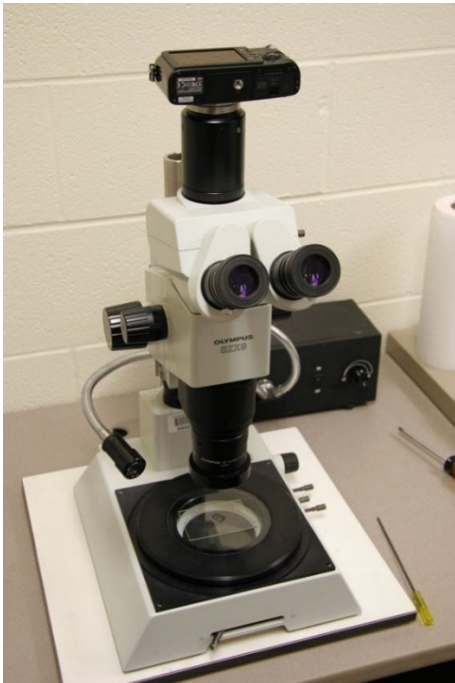


Fig. 4. Real and simulated machine for grinding and polishing LaboPol-1 with LaboForce-1 head

3.4. Simulation of Olympus SZX9 microscope

The observation under the light microscope is carried out by positioning the sample under the selected objective (if the microscope has a revolver allowing for quick lens change), looks into the eyepiece and focuses using the macrometric and micrometric screws. The model of the Olympus SZX9 microscope with a single objective magnification of up to 9 times was used for the simulation (Fig. 5).

a)



b)

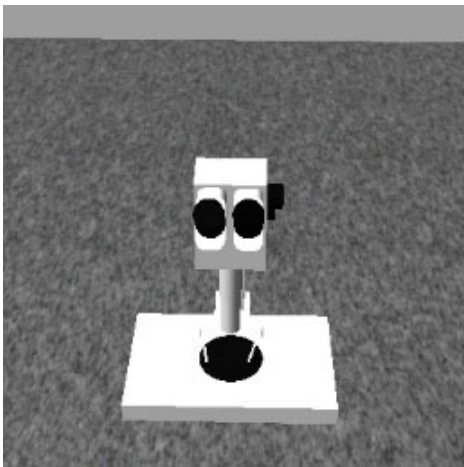


Fig. 5. Real and simulated Olympus SZX9 microscope

4. The course of the game

After starting the game, the user must move his character to the sample tray. It is located on the left side of the stage as it appears in the game. The user must walk up to the sample table and retrieve the appropriate sample. The character that the user moves around the scene is moved using cursor keys or the "W" (forward movement), "A" (left movement), "S" (backward movement), "D" (right movement) keys, and rotated using mouse gestures. We observe the scene through the eyes of our character. The object manipulation menu is invoked with the "E" button. The simulated machine is operated either by using the corresponding buttons placed in the same places as on the real machine or from the additional menu of the machine placed on the left side of the screen. In case of trouble, when it is not clear what to do at a given point in the game, the user can rely on the hints that appear in the blue hint box on the screen.

After taking the material from the table in the next step, approach the cutter, which is located on the table on the opposite side of the room, and cut the sample. When the user is in the right place, on the front of the device, the "E" key is used to enter the menu for operating the device. Following the procedure, using the appropriate functions from the device's menu, the user must open the machine's cover, insert the taken material into the cutter (Fig. 6), lock it and close the cover. Then start the blade and pull down the lever to place the rotating blade on the material and cut the appropriate sample. After the sample is cut off, the user should push the lever back up, stop the cutting blade, open the machine cover and remove the sample from the cutter. Pressing the "E" key again exits the menu of the operated machine and exits back to the game scene.



Fig. 6. Gameplay in progress. The cover of the cutter is open, the material has been placed and locked in position

With a properly cut sample, the user should approach the hydropneumatic press for hot inclusion. To operate the machine, the user should approach it and activate the machine's menu. Then, following the instructions, the user should unscrew the piston cover in the simulated machine, pull out the table, place the sample on it, slide the table into the machine, add resin and screw on the cover. Now the process can be started by clicking the "Start" button. When the sample has been embedded in the resin, you need to remove it from the machine, following the above steps in reverse order, and move it to the next device.

The next step for the user is to grind the sample. It is necessary to place the sample in the grinding head. After the user will move his character to the right place, in front of the grinder, user needs to attach the sample to the machine head and open the control panel. To turn on the grinder, press the green button. After the grinding and polishing process, the machine must be turned off with the red button on the control panel. Then the user needs to take the sample out of the machine head.

Now the user can approach the microscope and observe the polished sample. Once the user places the sample under the objective, he should sharpen the image to get a satisfactory image by clicking the "plus" or "minus" buttons responsible for coarse and fine adjustment.

Achievement of the goal, which means obtaining a quality image of the microstructure, will be announced with the comment "Mission accomplished" (Fig. 7). This marks the end of the game.

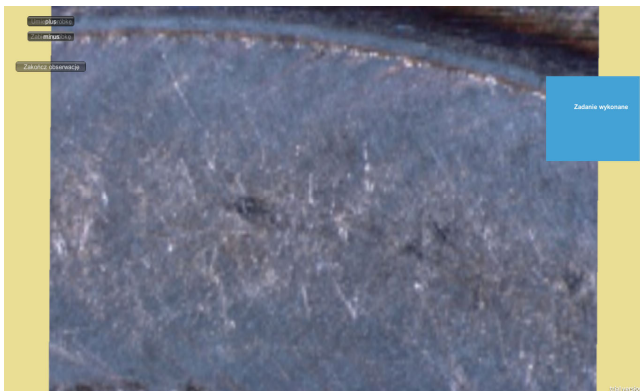


Fig. 7. "Mission accomplished". You can observe the microstructure of the sample. The game is over

5. Conclusions

Virtual Lab is a modern educational tool available to all users. The form of a 3D game used in this study is an interesting alternative to traditional teaching aids. It can be

used not only by students but also teachers and other people who want to broaden their knowledge about the functioning and methods of operation of laboratory equipment. It shows in a simple way how to prepare a material sample so that it is possible to observe its microstructure on a light microscope.

Thanks to highly developed computer tools for three-dimensional modelling, it is now possible to recreate the appearance of all machines and devices, including laboratory devices. This allows them to present their work away from their real counterparts, making it possible to conduct training using even one computer with a projector. Computers, thanks to computer science armed with appropriate educational software, became one of the most interesting teaching aids, giving great opportunities to expand knowledge, skills and abilities.

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