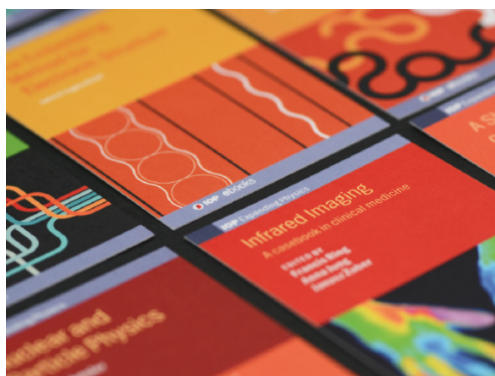


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Animated mixed reality models for teaching solid state physics

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Abstract. The article deals with the preparation of animated content for mixed reality systems in solid state physics. The main obstacle to the mass adoption of these technologies is the complexity of model development. Here we have proposed one of the possible ways to simplify the creation of three-dimensional models for a course in solid state physics. In turn, the volumetric model can be supplemented with animated effects, which will provide greater interactivity and information content of the processes and phenomena under consideration. The proposed scheme is used to create models for the preparation of future physics teachers both in the process of teaching physics and directly for developing models. A survey was conducted among students about the complexity of developing such models. The results obtained testify in favor of the use of such methods both in teaching physics itself and in forming a base of models.

1. Introduction

The trends prevailing over the past year in the educational process of students have exposed a number of difficulties in approaches, technological and software bases [1, 2]. In particular, one of the problems is the slow development of software models and their maintenance. Attention was directed to this complexity in our work [3], the results of which were obtained even before the massive transition to the remote learning process.

In this article, we consider one of the mechanisms that make it possible to simplify the development of three-dimensional models in solid state physics, as well as to provide their animation. The need for content development is emphasized in many works devoted to modern virtual learning technologies. This is often a complex process that requires deep specialized knowledge of 3D design and modeling. This, in turn, complicates the development of visual models for specific areas, for example, in physics. The authors of the work [4] also address the issue of attracting students to the development and implementation of mixed and virtual reality systems. Here, the features of teaching physics and honing teaching skills are considered, which will undoubtedly be useful for future teachers.

Let's turn to the latest trends and results in this area. So in works [5-7] it is said about the still insufficient rate of implementation of mixed and virtual reality technologies in a physical experiment both in the lower grades and at the subsequent stages of education. Traditionally, one of the advanced areas of VR application is medicine and related fields, for example, work [8] provides a study of the



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adaptation of integrated laboratory work on macroanatomy in medical physics. In [9] an example of the use of equidistant projections in teaching physics, which in our opinion is somewhat difficult, but the authors of the work managed to obtain interesting results. This technology was also tested by us in [10], where spherical images were designed to complement the field practices of students in geography. The direction associated with gamification continues to develop in the study of physics [11-13] and related sciences.

In turn, there is a demand for the visualization of scientific results in the form of elements of mixed and augmented reality, as the authors of [14] demonstrate the development for visualization of diffraction data in order to reduce the likelihood of errors in their interpretation.

2. Methods and Approaches

The work uses a number of different methods and technologies. The construction of the models themselves was carried out using the molecular dynamics method in the LAMMPS software package [15]. This makes it possible to create fairly realistic models at the atomic level of objects such as dislocations, point defects, nanopores, planar defects, as well as various processes in dynamics. Then the data is exported to a text file with the characteristics of the models of interest to us.

The next step is to prepare the obtained data using the Paraview analysis and visualization application [16]. At this stage, the appearance of the model is adjusted and the necessary visualizers are applied. Then the resulting model was exported to the Polygonal file format, suitable for further work in the Blender software package [17]. Blender was used to customize the appearance of the models and animate them with subsequent export to GLB format.

The final stage consisted in downloading the obtained models to devices suitable for demonstration. ClassVR virtual and mixed reality headsets were used as such devices [18]. The download was carried out via a web interface via a wi-fi network.

To analyze the methodological features of the developments, the method of polling students studying according to the profile of training: physics and computer science was used. The survey consisted of two questions, each with three possible answers: "yes", "no" and "abstained". The first question: "Did animated 3D models for virtual and mixed reality headsets allow you to understand in more detail the peculiarities of defect structures in crystals?" The second question: "Are you ready to independently develop such models in your future professional activities?" Further, the analysis and processing of students' answers were carried out, similar to our work [19].

3. Results and discussion

According to the proposed scheme, a number of models have been developed on the topic of crystal lattice defects. In this part, we will consider in more detail the stages of development using the example of one model.

Data exploration can be performed interactively in 3D or in software using ParaView's batch processing capabilities. To display all the characteristics of the atoms of the model, select all values in the Mesh and Point sections (figure 1.a). Next, you need to connect modifications in order to make the visual picture more attractive. First, we change the color and shape of the model particles. Color is set for each "layer" separately. You can use either solid colors or a gradient according to some characteristic (coordinate, type, speed, energy, etc.) as colors. An important condition is the presence of the displayed characteristic in the output file from LAMMPS. The color change is carried out in the appropriate section by choosing the desired characteristic from the list presented, depending on your needs. In our case, item `c_2` (energy) was selected. In addition, you can change the size and display of the particles. Note that, by default, particles are displayed as flat squares. The size is determined by the Point Size characteristic. For a more beautiful display, select Point Gaussian in Representation. Also in the Point Gaussian section, you can change the radius and shape (sphere, triangle, etc.).

Before converting a model to 3D format for further work with it in Blender, you need to make a number of settings. Clicking on the Glyph filter opens the advanced settings menu. In it, we select the display of atoms as spheres and apply this to all atoms.

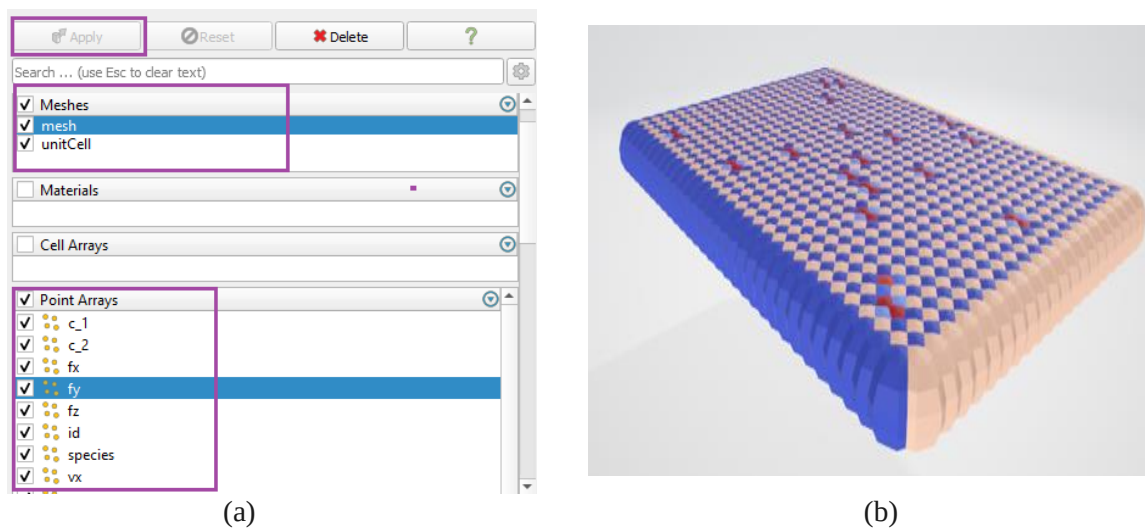


Figure 1. Visualization of the model: (a) selection of loadable model characteristics in Paraview; (b) render result in Blender 3D.

We export the data keeping all the properties described above. Importing the saved data into Blender. In the File - Import - Stanford (.ply) menu, launch the unloaded model. Go to the Material Properties section to add a new material. It is important to check that the Use Nodes button is active. You need to bind the colors to the material. To do this, place the attribute to the left of the main shader block and bind the Color property to the Base Color property. To see the result, you need to go to Shading. We export the finished 3D model in glTF 2.0 format (.glb / .gltf). Next, we can check the file type (.glb) and the activity of materials (figure 1.b). When loading several steps from LAMMPS in the corresponding section of Blender, their sequential scrolling with animation creation is possible.

To analyze the methodological prospects for the use of models and the development technology itself, a survey was conducted of senior students with methodological competencies, as well as those directly undergoing training using these models. First of all, the students expressed an opinion about whether such models were informative when studying topics in solid state physics (figure 2.a).

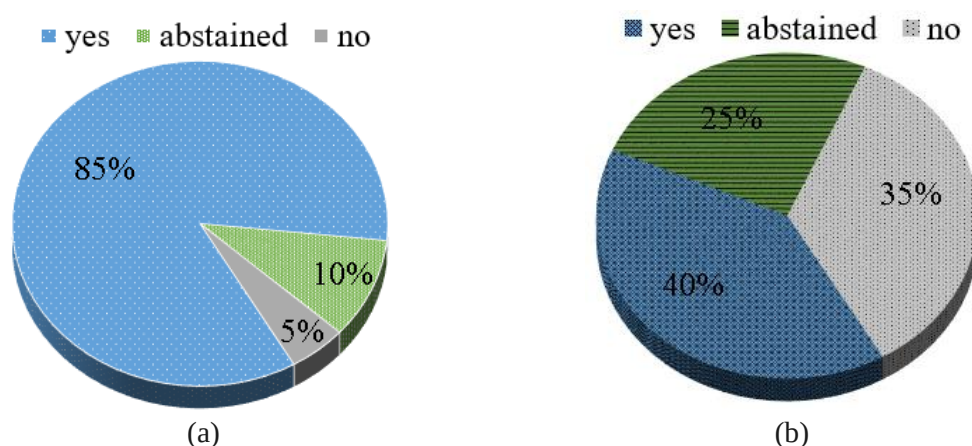


Figure 2. The results of the survey of students: (a) on the use of models in the educational process, (b) on the willingness to independently develop models.

Based on the survey results, it can be concluded that the use of such models is promising in the process of teaching students in physical specialties, in particular, in the study of solid state physics. At the same time, the development technology itself obviously caused difficulties for students, since only

40% expressed the opinion that they are ready to create such models themselves. At the same time, 35% said “no” to the same question and 25% abstained. These results show that the majority of students, even after training, are not ready to independently develop content for virtual and mixed reality headsets.

4. Conclusion

The article proposes an approach to the development and preparation of 3D animated solid state physics models for virtual and mixed reality headsets. The stages are described and the mechanism of preparing the model for loading on virtual and mixed reality headsets is described in detail. Attention is focused on converting text data into a form suitable for building three-dimensional models and their animation.

Also, a survey of senior students was conducted on the advisability of using such models in the educational process and the complexity of independent development. More than 85 percent are in favor of using such training tools, but only 40 percent are willing to develop such models themselves. The main reason for the difficulties in detailed analysis was the initial stage of building a model in the molecular dynamics software package. The solution to this problem will be considered in subsequent works. The content of this work can be useful for physics teachers, content developers for virtual and mixed reality headsets, as well as undergraduate and graduate students in this field.

Reference

- [1] Abakumova I, Zvezdina G, Grishina A, Zvezdina E and Dyakova E 2020 University students' attitude to distance learning in situation of uncertainty *Innovative Technologies in Science and Education (ITSE-2020)* **210** 18017
- [2] Pei L, Li J, Li B and Zhao R 2020 Distance Learning System Design in Edge Network *International Conference on Computer Engineering and Networks* **10** 1291-97
- [3] Zakharov P V, Vdovin R S, Markidonov A V, Kochkin A S and Vdovin A S 2020 Virtual and mixed reality in the study of the geometry of the crystal lattice *Journal of Physics: Conference Series* **1515** 022001
- [4] Chini J J, Straub C L and Thomas K H 2016 Learning from avatars: Learning assistants practice physics pedagogy in a classroom simulator *Physical review physics education research* **12** 010117
- [5] Jiugen Y, Jing Y and Ruonan X 2020 Design Research of Physical Virtual Experiment Based on Virtual Reality Technology *15th International Conference on Computer Science & Education* (Netherlands: Delft) pp 262-6
- [6] Wang W and Wang Y 2020 Study on the Reform of the Physics Experimental Teaching in University Based on Virtual Reality Technology *IEEE 2nd International Conference on Computer Science and Educational Informatization (CSEI)* (China: Xinxiang) pp 58-62
- [7] Liu Q, Yu S, Chen W, Wang Q and Xu S 2020 The effects of an augmented reality based magnetic experimental tool on students' knowledge improvement and cognitive load *Journal of computer assisted learning* 1-12
- [8] Kang E S, Popovic M and Noel G 2020 Integration of gross anatomy laboratory sessions into medical physics curriculum *Medical science educator* **30** 1765-73
- [9] Yavoruk O 2019 Teaching physics using equidistant ar/vr-projections *International conference on digital technology in education* **3** 48-51
- [10] Zakharov P V, Eremeev E A, Bavykina E N and Makarova O N 2020 Virtual reality technology in the preparation of geography teachers *International Conference on Economic and Social Trends for Sustainability of Modern Society* 709-16
- [11] Lorenzo Alvarez R, Rudolphi Solero T, Ruiz Gomez M J and Sendra Portero F 2019 Game based learning in virtual worlds: a multiuser online game for medical undergraduate radiology education within second life *Anatomical Sciences Education* **13** 602-17
- [12] Sharhorodska O 2019 Implementation of an immersive virtual astronomy laboratory using gamification techniques aimed at high school students *17th LACCEI International Multi-Conference for Engineering, Education and Technology* (Jamaica: Montego Bay) pp 1-7

- [13] Iquiria D, Sotelo B and Sharhorodska O 2019 A Gamified Mobile – Based Virtual Reality Laboratory for Physics Education: Results of a Mixed Approach *International Conference on Human-Computer Interaction* vol 1034 (Springer: Cham) pp 247-54
- [14] Knot A, Mammen S, Gao Y and Thorn A 2020 Immersive Analysis of Crystallographic Diffraction Data *ACM Symposium on Virtual Reality Software and Technology* **58** 1-3
- [15] Information on LAMMPS Molecular Dynamics Simulator on <http://lammps.sandia.gov>
- [16] Information on ParaView Multi-platform Data Analysis and Visualization Application on <http://lammps.sandia.gov>
- [17] Information on Blender Software for Creating Three-dimensional Computer Graphics on <https://www.blender.org/>
- [18] ClassVR Virtual Reality Headset. *Avantis Systems Ltd. Gloucester (UK)* Available to view at: <http://portal.classvr.com/>
- [19] Zakharov P V, Kateva A S, Kochkin A S, Eremin A M and Markidonov A V, 2020 Some aspects of using mixed reality technologies in the training of physics teachers *Journal of Physics: Conference Series* **1691** 012015