Virtual reality as a tool for training specialists in the field of radiation non-destructive testing

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Abstract. Organizational, technical and methodological approaches to the creation and application of virtual reality in additional education are considered. Particularly for use and development of a digital radiography simulator in non-destructive testing of products and materials. It is noted that virtual reality technologies are most widely used in training and knowledge testing of engineering and technical personnel and workers in production, as well as in technological preparation during complex and exacting operations, including products and materials testing. The pilot solutions obtained and tested to date allow us to evaluate the results of complex scientific research. The prospects of expanding the applicability range of software and hardware virtual reality solutions, including those based on network interfaces, protocols and telecommunications solutions, are determined.

1. Introduction
There are virtual reality (VR) systems of various architectures, functionality, complexity and cost, for example, for radiodiagnostic simulation in medicine. This helps to train the preparation and conduct of various X-ray inspections of organs and human body's systems [1].

Aside from medical radiology method, there are solutions for distance education in the field of digital radiography on the market, offered, for example, by the American Institute of Non-Destructive Testing (NDT) [2], however, with rare exceptions, they do not use software and hardware VR solutions and artificial intelligence systems for training and examination of non-destructive testing specialists. Nevertheless, it should be mentioned that the public release of the software for training in radiographic method of non-destructive testing TraiNDE RT, based on a virtual software environment, was announced not so long ago by TraiNDE (https://trainde.extende.com). The mentioned solution is a VR software associated with a database of predefined X-ray NDT results, which reproduces testing conditions for various samples (welded pipes and plates, cast samples, etc.) with image quality indicators (IQI), typesetting bar with lead letters and X-ray flexible rulers.

2. Objective statement
According to the statistics of the world's leading production and technology companies, VR technologies are most in demand and widespread in solving the tasks of training and testing of engineering and technical personnel and workers directly employed in production, as well as in technological training in the development of complex and critical operations, including non-destructive testing. Due to the
didactic material's presentation method that brings the student as close as possible to the real production environment, it is possible to reduce the time and significantly improve the quality of specialists' practical training [3].

The analysis of available data shows that at the moment the classroom-based method of teaching is known and widely used [4-9]. It includes monitoring the assimilation of educational material according to the established NDT types and methods classification [10], the use of physical testing objects as well as physical NDT equipment [7].

Practical skills are developed in specially equipped NDT type and method-specific laboratories, which are subject to specific industrial and radiation safety requirements. Laboratories are equipped with a specialized rooms infrastructure, with expensive technological equipment, devices and tools, physical objects and consumables for non-destructive testing, according to the established classification [5-8].

Among the disadvantages of the classroom-based teaching method are: limited audience coverage, the requirement for a classroom fund and specialized laboratory facilities, the requirement for equipment with specialized furniture, video and image projectors, multimedia and technological equipment, devices and tools, NDT consumables. In addition, a significant disadvantage is NDT-related industrial waste and their following disposal according to the categories of industrial waste.

The objective of R&D was to remove these shortcomings of the classroom-based teaching method through the development and application of VR technologies and, as a result, to increase the effectiveness of training and examination of the student's knowledge by reducing material and time consumption for the entire training cycle, thanks to the use of digital educational resources in the form of didactic materials prepared and uploaded to a personal computer, digital duplicates of testing objects and NDT equipment in a virtual environment (figure 1-2).

3. **Looking for a pilot solution**

The generalized sequence of user actions proposed for software implementation for teaching non-destructive testing in a virtual environment is presented in the form of a diagram in figure 3.

Figure 4 illustrates the pictograms [10] of the subject and objects that are involved in the process of NDT teaching and practicing in a VR environment.

A radiation type of NDT and a radiographic method of receiving source information were chosen as a "pilot" ones for trial of the NDT teaching method [11].
This situation is determined by the fact that the specified type and method of non-destructive testing, according to experts, is very popular and occupies an impressive part of the total volume of all non-destructive testing operations in the industrial sectors of the economy.

![Diagram of user actions during training in a virtual environment]

**Figure 3.** The sequence of user actions during training in a virtual environment.

The development of a radiography simulator for non-destructive products (welded joints in particular) and materials testing required a whole complex of interdisciplinary research utilizing modeling tools and virtual reality technologies.

![Diagram of subject and objects of NDT training]

**Figure 4.** The subject and objects of NDT training. 1 – a user as a member of the educational process, 2 – personal computer with the monitor and appropriate software, 3 – keyboard, 4 – mouse, 5 – speaker system, 6 – a virtual reality helmet, 7 – joystick controller, 8 – printing device.

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4. Radiography simulator and its advantages

The development of a radiography simulator for non-destructive products (welded joints in particular) and materials testing required a whole complex of interdisciplinary research utilizing modeling tools and virtual reality technologies.

The resulting software and hardware solution includes a radiography simulator with a set of various educational scenarios that "immerses" the student in a virtual environment and allows him to dynamically interact with the method and technique-specific objects using software-algorithmic and mathematical models, NDT specialist's decision support systems, also during his technological training by "augmenting " the generated image with auxiliary graphics and/or factual information view. For these purposes, special elements are used to provide additional information in the form of text, graphic and audio prompts available to the user of the environment during an interactive session.

The main virtual scenes of the radiography simulator for training in non-destructive testing are shown in figure 5-8.

The key aspects and advantages of the virtual simulator's software development completion are listed below:

Economic: reducing the time and financial costs for training specialists, reducing the cost of owning a virtual radiographic laboratory.

Educational: software and hardware solutions of such kind allow you to increase a potential audience reach, keeping an individual educational trajectory options for each student.

Industrial: the constant growth of qualified NDT specialists' demand, which is inextricably linked with the continuous expansion of industrial geography, an increase in the amount and spectrum of high-tech industrial facilities under construction.

Environmental: reduction of the negative impact of ionizing (X-ray) radiation during practical training on both the student and the external environment.
5. Conclusion
The considered digital computer technologies and related solutions are in demand in various sectors of the economy and industrial production, where a broad variety of types, methods and techniques of non-destructive testing are widely used.

R&D was carried out using the following source environments and platforms for developing VR applications: Microsoft Visual Studio 16.4.6; Microsoft .Net Framework 4.8.03752; Unity3D Editor 2019.4.12 f, VR Toolkit 3.3.0, Blender 3D 2.91.2. For modeling – software solutions and data analysis tools: Python, NumPy, Pandas, SciPy, scikit-learn, DEAP, matplotlib.

The "pilot" software solution made and tested in laboratory conditions in sum allows to assess both the current results of complex scientific research and the expected final product results, namely: automation of the test tasks’ generation procedures; knowledge test based on mathematical models, artificial intelligence methods and software tools; reduction of training periods and increase in the number of specialists trained; increasing the functionality and evolutionary development of a software and hardware solution (radiography simulator) based on utilization of a unified modular approach when creating and using cross-platform software libraries and network hardware and software interfaces.

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