PROFESSIONAL PERSONNEL TRAINING

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VR/AR technologies and staff training for mining industry

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Abstract
Personnel working at mining enterprises must be prepared to overcome professional difficulties and to possess the professional competencies required not only for the implementation of processes, but above all their safety. Modern digital modeling technologies used in mining activities expand the boundaries of practical training not only for future mining engineers, but also for working specialists. As part of the training process, it is important that the simulation of the mining environment be of a high quality almost indistinguishable from the actual environment. In this context, the development of process solutions based on virtual and augmented reality (VR/AR technologies) is most relevant. Process automation in the conditions of large-scale digital transformation laid the foundations for the development of VR/AR in mining industry. Data analysis shows that VR/AR technologies are the major consumer of IT solutions. They are in fact the integrator, or the highest "IT-transformation", which in practical terms create digital parallel production objects and processes. Further developments in this area may also change some of the existing traditional entities or create new ones, in the training system as well. An example of such an entity, on which the digital future will depend, is the emerging "digital culture". As such it will be applicable not only in the corporate, industry, but also nationally. Despite the diversity of areas in the development of VR/AR technologies, the maximum effect of their implementation is manifested in the development of special skills of personnel in equipment operation. This clearly relates to the need to ensure the efficiency and reliability of technological operations and processes. The interaction between the consumer and producer of VR/AR solutions together with universities allows a number of problems related to the formation of competencies in the future generation of specialists to be resolved. These include: training of university graduates; creation of specialized courses in educational programs; individual higher educational programs; professional development and retraining courses for specialists in the field of VR/AR technologies in mining; involvement of the academic community representatives in the development of practical tasks based on VR/AR solutions, including researchers of different specializations (geology, geophysics, geotechnics, geoinformatics, aerology, geotechnology, mining machinery and equipment, automation, etc.). Other key areas include the dissemination of the best practices of VR/AR usage in the interests of future customers; creation of a common method to assess the effectiveness of VR/AR projects to determine their investment attractiveness; as well as prediction and creation of future technologies.

Keywords
mining, mining engineer, mining engineering education, IT technology, virtual reality, augmented reality, VR/AR technology, processes, process safety

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ПОДГОТОВКА ПРОФЕССИОНАЛЬНЫХ КАДРОВ. ОРГАНИЗАЦИЯ ИССЛЕДОВАНИЙ

Научная статья

VR/AR-технологии и подготовка кадров для горной промышленности

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Аннотация
Персонал, работающий на горных предприятиях, должен быть готов к преодолению профессиональных трудностей, обладать профессиональными компетенциями, которые связаны не только с реализацией технологических процессов, но и прежде всего с их безопасностью. Современные технологии цифрового моделирования горных производств могут расширить границы практической подготовки не только будущих горных инженеров, но и работающих специалистов. В процессе обучения важно обеспечить высокий уровень симуляции производственной горнотехнической среды воспринимаемой человеком практически в качестве реальной. В этом контексте развитие технологических решений на базе вирту-

альной и дополненной реальности (VR/AR-технологий) становится наиболее актуальным. Основу фундамента развития VR/AR в горном деле заложила глубокая автоматизация технологических процессов в условиях масштабной цифровой трансформации. Анализ данных показывает, что именно VR/AR-технологии становятся потребителем большинства IT-решений, являясь по сути интегратором, или высшим «IT-переделом», практически ведущим к цифровым параллельным производственным объектам и процессам. Дальнейшее развитие событий в этом направлении может изменить и некоторые существующие традиционные сущности или создать новые, в том числе в системе подготовки кадров. Примером таких сущностей, от которых будет зависеть цифровое будущее, может стать формирующаяся «цифровая культура», которая будет применима не только в корпоративном, отраслевом, но и в национальном аспекте. Несмотря на многообразие направлений развития VR/AR-технологий максимальные эффекты от их внедрения проявляются в формировании специальных навыков персонала в работе с оборудованием, что четко увязывается с необходимостью обеспечения эффективности и надежности технологических операций и процессов. Взаимодействие потребителя и производителя VR/AR-решений вместе с университетами позволяет решить класс задач, связанных с: формированием компетенций у будущего поколения специалистов – выпускников университетов; созданием специализированных курсов в образовательных программах, а также отдельных образовательных программ в высшем образовании, курсов повышения квалификации и профессиональной переподготовки специалистов в области VR/AR-технологий в горном деле; вовлечением в процессы разработки практических задач на основе VR/AR- решений представителей академического сообщества – исследователей разной специализации (геология, геофизика, геомеханика, геоинформатика, аэрология, геотехнологии, горные машины и оборудование, автоматизация и т.д.); распространением лучших практик использования VR/AR в интересах будущих заказчиков; созданием единой методики по оценке эффективности внедрения VR/AR-проектов для определения их инвестиционной привлекательности; прогнозированием и созданием будущих технологий.

Ключевые слова
горное дело, горный инженер, горное инженерное образование, IT-технологии, виртуальная реальность, дополненная реальность, VR/AR-технологии, технологии, технологическая безопасность

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Introduction

Mining is associated with significant process risks, the assessment of which is made complicated by the specific nature of the processes, as well as a high level of natural uncertainty in the description of objects, processes and their models. Despite the achievements of researchers, much of mining is affected by phenomena which are very difficult to predict [1–3]. Throughout the history of mining, there have been major accidents with severe consequences. Mining engineers, for various reasons, felt helpless in their attempts to predict these disasters [2]. Naturally, the most difficult situation lies in the types of geotechnologies associated with underground mining (underground geotechnology, construction geotechnology). This is due to the complicated mining and geological conditions, a significant number of process factors (dust factor hazard, methane content, ventilation systems and many others), as well as particularly difficult working conditions (lack of natural lighting, contamination of the mine atmosphere, significant physical stresses, etc.). The personnel working at mining enterprises must be prepared to overcome professional difficulties and possess professional competencies required not only for process implementation, but their safety [4–6]. It is for this reason that same or very similar disciplines related to mining safety are taught in practically all the curricula for mining engineers training curricula in specialized universities of the world [7]. These include such disciplines as: ventilation (aerology); mining safety; blasting safety; geotechnics; geophysics; methane safety, etc. [8–10]. Naturally, the autonomy of universities leads to different interpretations of these disciplinary areas, but the essence is the same. Everything is aimed at ensuring that the future mining engineer is qualified to make the right decisions in production conditions, in order to ensure effective implementation of processes and to minimize risks of injuries and accidents in general [11–13].

A special role is played by practical training programs in which real production conditions provide theoretical training of future mining engineers who in this way adapt to real working teams, which is of great socio-professional importance [14, 15].

Practical training in education implies the student's activity in the conditions of real production. However, in this case its scope is limited by the duration of training. In fact, in the case of a four-year bachelor's degree program in mining engineering (international practice), as offered in many countries, there is not a great time resourcefor lengthy practical experience. At the same time, the training of mining engineers-practitioners is extremely important [16]. In Russia and a number of other countries, educational programs in mining engineering are implemented at the level of a specialist's program with 5.5 years program of studies. This forms conditions for the concentration of rather lengthy practical cycles (2–3 months) with the total duration for the whole term of study of more than 7 months [17]. However, even under these conditions there is always themutual desire to increase its scope– both on the part of universities and the employers. Of course, compromises are necessary to achieve the golden mean between the theory and practice. However, modern digital modeling technologies in mining production can expand the limits of practical training of the future mining engineers and working specialists. This is especially true when, for example, a given enterprise is undergoing large-scale modernization associated with upgrading of equipment and process solutions. This concerns not only traditional simulators, whose purpose is to develop the specialized professional skills at the training stage. It is important to provide high quality simulation of the production mining environment as close to the real environment as possible. In this context, the development of process solutions based on virtual and augmented reality (VR/AR technologies) is most relevant [18, 19] in terms of improvement of practical training within the framework of educational programs, including universities.

Areas for VR/AR development in mining

The mining industry is one of the first industries to use VR/AR technologies in its activities. Throughout its historical development, it has had to deal with a broad range of complex economic, operational and now environmental and social challenges. Over the past 10 years, the global mining industry has invested about 0.5 % of its income in research and development into VR/AR technologies[1].

The intense automation of processes in the conditions of large-scale digital transformation laid the foundation for the development of VR/AR in the mining industry [20]. The use of a significant variety of IT solutions at all stages of production cycles of mining enterprises has been observed (Table 1).

Data analysis shows thatVR/AR technology is the primary consumer of these solutions. They are the main integrator, or the highest "IT transformation" leading to the creation of digital parallel production objects. Further development in this area may also change certain traditional entities or create new ones, also in the staff training system. One example, upon

[1] Fade L. How virtual & augmented reality are revolutionizing the mining industry. URL: https://vrvisiongroup.com/how-virtual-augmented-reality-are-revolutionizing-the-mining-industry/

Table 1

World practices of using IT solutions in mining

IT solution	Scope of application	Examples of application, distinctive features
Mining simulators	Simulation training	Simulators place trainees in a controlled production environment
Underground telecommunications	Underground wireless technology	Communication between workers in the mine and the control site on the surface. Real-time data collection of equipment performance allows rapid response to failures and problems
Personnel tracking	Radio frequency identification of miner's metrics	Instantaneous identification of the worker's location to avoid downtime, errors, and human error
Microseismic monitoring	Monitoring of changes in the structural integrity of the working area	Evaluation of the rock mass phenomena severity, determination of geotechnical safety of mine workings and preventive measures before a catastrophic event or accident
Drones [21]	Positioning underground	Displaying of excavation topology, including the condition of their walls surface
Protective equipment	From gas detection devices to clothing that cools personal protective equipment (PPE)	Real time gas sensors. Cooling vests and other clothing items
Mining data	Analysis of data obtained from innovative equipment. Prediction of the state of production processes	Improvement of all production processes, including logistics
VR/AR technologies	Repairs and maintenance, inspection (audit) and work control, training and coaching of employees	Possibility of team training, including practicing of synchronization of operations. Using VR/AR technologies, the staff not only learns and memorizes the order of operations, but also visually practices actions at each stage of work

which the digital future will depend on, could be the emerging digital culture, applicable not only in corporate industry, but also in the national aspect. Digital culture is understood by experts to be a set of competencies which determine the ability to use information and communication technologies for convenience in a digital environment, interaction with society, and digital tasks in professional activities.

According to the study carried out by PwC, the development of digitalization in the industry will require variability and flexibility in terms of professional competencies on the part of the personnel. The accelerated integration of artificial intelligence in the sphere of industrial production and work in dynamic data environments by means of the implementation of IT solutions will require the transition from linear education to lifelong learning[2] [22].

Practice of introducing VR/AR in the mining sector of Russia

Russian mining companies use VR/AR for a range of different purposes. Interesting studies in terms of evaluating the level of introduction of virtual and augmented reality technologies have been conducted by CapGemini and TAdviser (Russian business sector)[3].

The following basic areas were identified:

1) digital methodological support and simulators for assembly and integration processes for equipment of high-level complexity (virtual training centers);

2) simulators for working in the conditions of elevated hazard;

3) support for the activities of operating personnel (remote expert);

4) evaluation of the load and operating modes of equipment in real time;

5) assessment of the suitability of virtual models to the real physical characteristics and parameters of equipment and processes;

6) creation of archives, including visual ones;

7) solving the problem of visualization of a "digital twin", also from different and hard-to-access positions and conditions;

8) virtual and visual description of hazardous production zones.

Companies are faced with a wide range of problems, including process, expert and educational ones. Many of these problems are associated with ensuring

[2] Geissbauer R., Lübben E., Schrauf S., et al. How industry leaders build integrated operations ecosystems to deliver end-to-end customer solutions. URL: https://www.strategyand.pwc.com/gx/en/insights/industry4-0/global-digital-operations-study-digital-champions.pdf

[3] Market of industrial VR/AR solutions in Russia Research of TAdviser. URL: https://www.tadviser.ru/index.php/Статья:Рынок_промышленных_VR/AR-решений_в_России_(исследование_TAdviser)

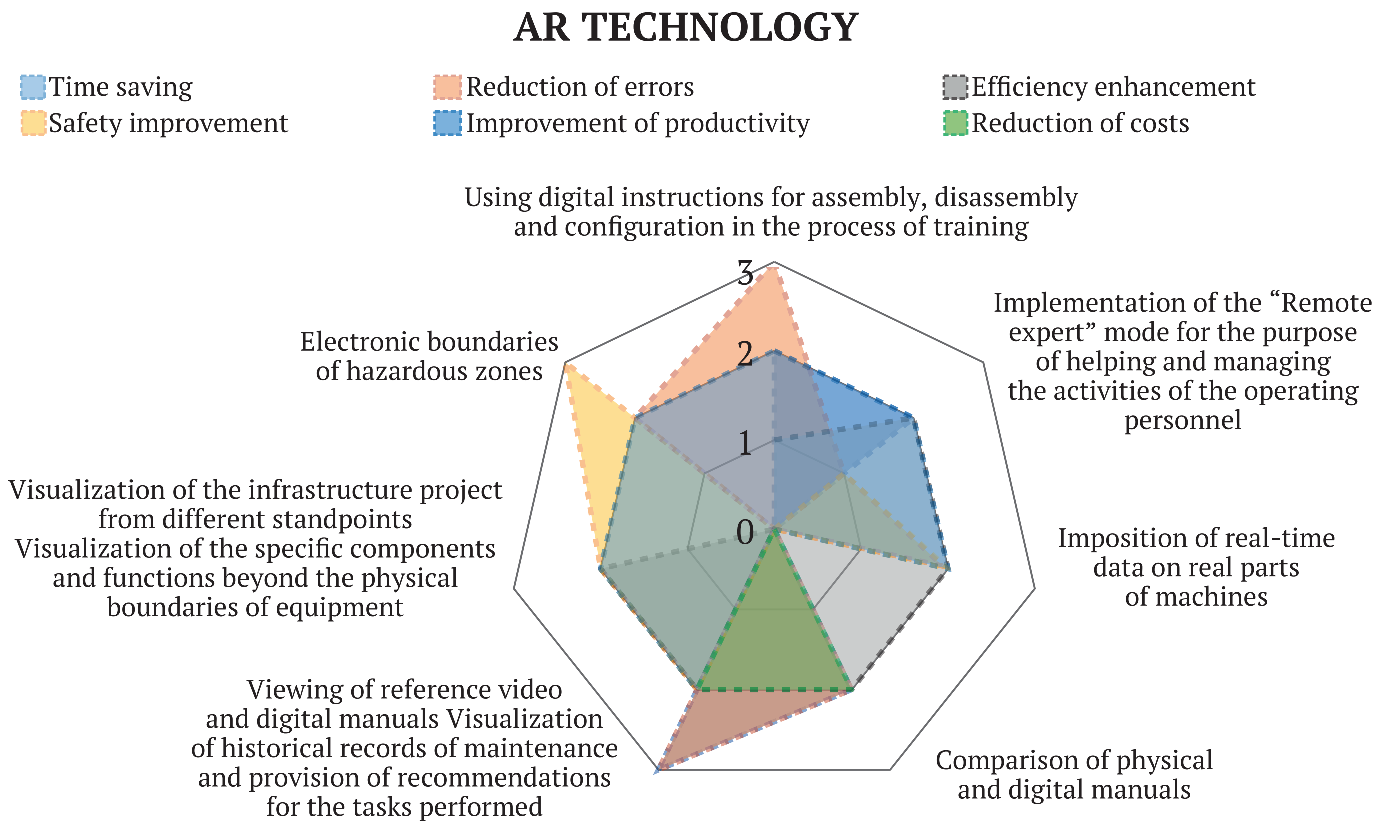

Fig. 1. Expected and real effect from the introduction of AR technologies (according to TAdviser research data)

safety in the conditions of hazardous technological production. There is a class of companies which have been developing corresponding competences through existing corporate centers and/or committees. These include: SIBUR; Severstal; GazpromNeft; EVRAZ; and Magnitogorsk Iron and Steel Integrated Works (MMK). Alrosa and the Siberian Coal Energy Company (SUEK) are also working in this area.

We will provide data with assessment of effects from implementation of VR/AR technologies in the mining complex of Russia (Figs. 1, 2).

This data indicates that the maximum effects of implementing VR/AR technologies are manifested in the formation of special skills of the personnel in working with equipment. This is clearly linked to the efficiency and reliability of technological operations and processes.

Examples of VR/AR solutions in the mining and metallurgical industries are presented in Table 2.

Some of the main challenges faced by companies when implementing VR/AR projects at mining enterprises are:

– significant financial costs required to build the necessary digital infrastructure to implement and adapt VR/AR technologies;

– lack of scalable solutions;

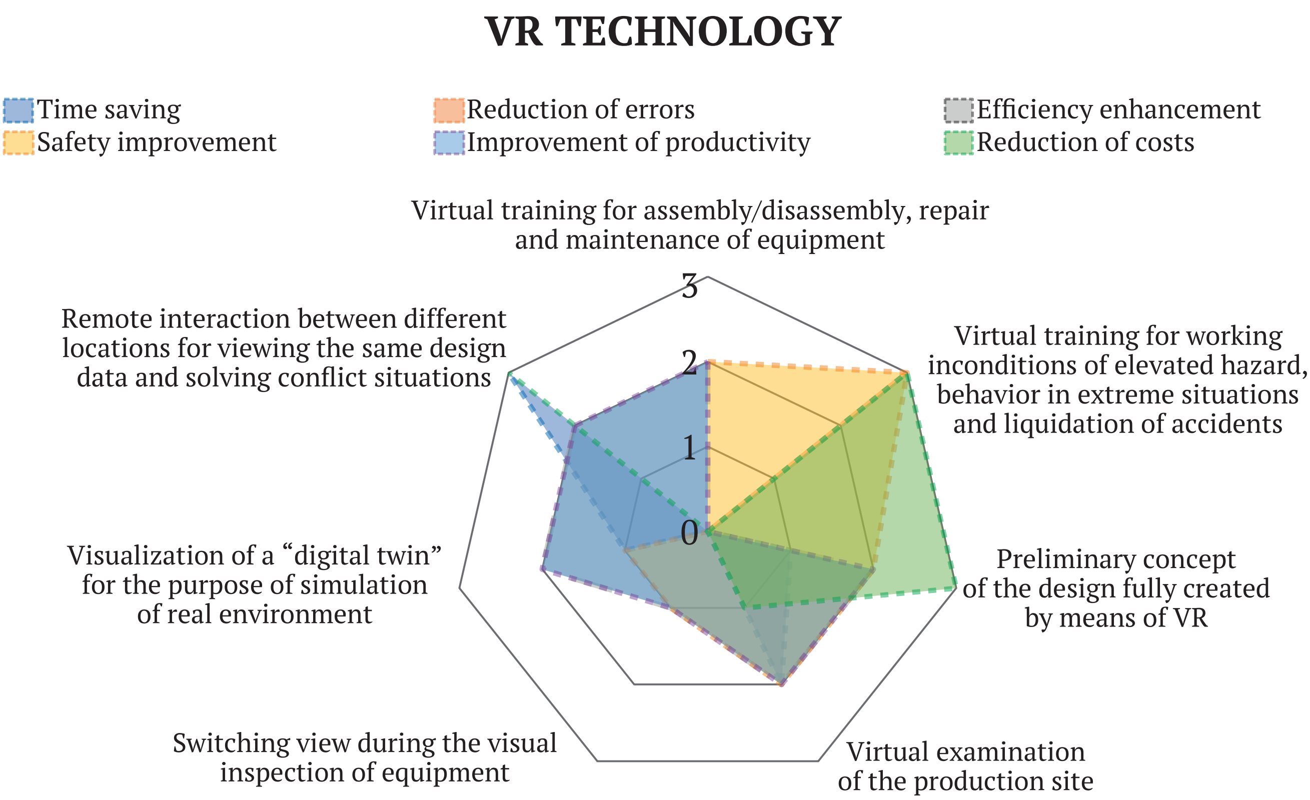

Fig. 2. Expected and real effect from the introduction of VR technologies (according to TAdviser research data)

Table 2

Examples of practical use of VR/AR in Russia

Company in Russia	SIBUR	Gazpromneft	Severstal	Magnitogorsk (MMK)	Evraz
Examples of use	Systems "Remote expert", "Digital assistant", interactive training, training in handling hazardous reagents	Systems "Remote expert", "Digital assistant", interactive training, training in handling hazardous reagents, virtual technological maintenance	Interactive instructions for disassembling and detection of flaws in pumping equipment, practicing of safety procedures and work in emergency situations, VR shop of the Cherepovets Metallurgical Complex	Virtual training in working in a high-risk environment. Virtual training for behavior in extreme situations and emergency response	Virtual examination of the production site

– lack of methods for calculating the efficiency of implementing such solutions. This introduces uncertainty into the parameters of investment projects;

– limited access to advanced process solutions;

– limited competence of the human potential (lack of qualified personnel at all levels)[4].

Role of VR/AR in training staff for the mining industry

In the context of the mining industry, the main advantages of the AV/VR technology are that it allows training in an environment close to reality, as well as the simulation of virtual scenarios [23]. Obviously, the introduction of virtual and augmented reality technologies in educational programs will require new methodological approaches which will take into account the level of specialists' training, their individual qualifications (installer, operator, dispatcher, mine rescuer, etc.), the number of trainees, and the new role of the teacher, etc. Evaluating the applicability of individual AR and VR technologies, developers also offer mixed MR solutions [24].

The training of operators and maintenance workers of sophisticated equipmenton simulators includes:

1) the process of continuous theoretical training;

2) working on simulators where practical situations at workplaces are practiced;

3) control of knowledge, skills and abilities;

4) working with instructions based on VR/AR solutions;

5) error correction, reinforcement of the correct action algorithms.

Approaches to the implementation of complex VR/AR solutions in the main educational programs for training industry specialists (bachelors, specialists and masters) are presented in a completely different way. A future mining engineer (the higher education level is specialist) should be prepared not only to undertake practice on simulator systems, but also be able to generate complex solutions based on expert evaluations in technological cycles or processes. In this regard, the use of VR/AR technologies in the mining engineer educational process need to be clearly linked with his/her future labor functions. Global practice shows that the best solutions for the formation and development of competencies in the field of the VR/AR environment are implemented by mining enterprises in partnership with universities.

The role of universities as the main concentrators of knowledge is associated with the requirements and expectations of industrial partners. This also involves the development of innovative educational programs and technologies. Universities not only train young specialists, bachelors and masters, but also transfer advanced competencies to the existing staff of enterprises. This in turn allows universities and advanced companies to build long-term partnerships. An indisputable advantage of universities is the state support, including financial support. This can lead to universities becoming centers of technological solutions based on VR/AR technologies. Modern state support of universities in Russia is based on the principles of co-funding of projects by business, which ensures the relevance of projects for the real economy. This approach also allows companies to receive financial support in the form of targeted subsidies from the federal budget under the national projects "Education" and "Digital economy" (subproject "Digital technologies") for the development of VR/AR technologies.

Conclusions

1. Virtual and augmented reality technologies recreate the comprehensive conditions and processes of mining production in high quality, contributing to the formation of professional competencies of personnel of various levels and qualifications. It is worth noting the special role of VR/AR technologies in ensuring the safety of mining operations.

2. Interaction between producers, consumers of services and their cooperation with universities play a great role in the development of VR/AR technologies. Such alliances allow a class of problems related to the formation of competencies in the future generation of specialists to be resolved. These include: the training of university graduates; creation of specialized courses in educational programs, as well as individual higher educational programs; and professional development and retraining courses for specialists in the field of VR/AR technologies in mining. Another outcome is the formation of the corresponding staff potential in general in the industry and not only on a corporate level. This also requires the involvement of the academic community in the development of practical tasks for VR/AR solutions. The researchers engaged in study come from a range of specializations: geology; geophysics; geotechnics; geoinformatics; aerology; geotechnology; mining machinery and equipment, as well as automation, inter alia. This also creates conditions for critical analysis and the improvement of specific solutions. The best practices of VR/AR usage are disseminated in the interests of future customers (market development) and contribute to the creation of a common method to assess the effectiveness of VR/AR projects, thus determining their investment attractiveness, predictability and the creation of future technologies.

[4] Why AR is more promising for the industry compared to VR? URL: https://news.myseldon.com/ru/news/index/221068050

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