360° Photographic Panoramas as an Effective Multifunctional Aid for Teaching Technology Subjects

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Abstract: Rapid development of modern machinery and its increasing complexity make high demands to the quality of training of its users. Among the variety of kinds, the important one is vehicles, both civil and military. In the teaching of associated subjects, there is an accepted hierarchy of teaching aids that includes common visual aids (posters, videos, scale models etc.) on the first stage, followed by simulators ranging in complexity, and finishing at real vehicles. It allows achieving some balance between cost and efficiency of training by partial replacement of more expensive and elaborated aids with the less expensive ones. However, the analysis of teaching experience in the Institute reveals that this balance is still suboptimal: the quality and abundance of common aids may be increased, and the simulators may be used more effective. This fact raises the problem of extending the range and quality of available teaching aids for vehicle-related subjects, which is the aim of the work. Benefiting from the modern information and visualization technologies, we present a collection of new teaching aids, which are based on 360° (spherical, 3D) photographic panoramas joined with H5P interactive content framework or virtual reality devices. The nature of the aids, their potential applications, limitations and benefits in comparison to the common aids are discussed, and the practical recommendations about creating and implementing the aids are given. The proposed aids are shown to be cost-effective and proven to increase efficiency of training, according to the results of a teaching experiment. For the implementation, a tight collaboration between the Institute and an IT company was established. The authors conclude that the proposed aids may significantly improve the cost-efficiency balance of teaching technology subjects.

1 INTRODUCTION

Technology plays a vital role in modern world. At present, most occupations and activities imply utilization of some devices and equipment. Among the variety of classes, an important representative is vehicles. A wide assortment is designed and extensively used in civil (transport, building, service etc.), military, and paramilitary (emergency, police) fields. The following features are typical for modern vehicles and their exploitation process:

- increasing complexity of the chassis itself and the installed equipment;
- fast development, resulting in frequent appearance of upgraded and novel models;
- often, hard use conditions (especially for military and paramilitary vehicles);
- high costs of repairing and replacement of broken samples.

Consequently, extensive knowledge about the proper exploitation of the vehicle and related skills must be delivered to trainees during education in order for them to become qualified users.

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2 RELATED WORK

In the teaching of vehicle-related subjects, there is an established and accepted hierarchy of teaching methods and corresponding aids (Course, 2019). It is summarized in table 1.

Table 1: The accepted hierarchy of teaching aids in teaching vehicle-related subjects.

Stage	Teaching aids	Goals
1	Common visual aids (posters, animations, videos, scale models etc.)	Provide the knowledge about the constitution, functioning, appearance, and exploitation of the vehicle. No skill developing is assumed.
2	Simulators	The purpose is two-fold. Firstly, providing information about appearance and exploitation of the vehicle. Secondly, a more or less wide range of skills may be trained, depending on the class of simulator.
3	Real vehicles	Providing real-world driving experience and developing exploitation skills.

An extensive literature, both pedagogical and technical, is available about the problems of design and use of simulators (Rusilo, 2010; Rudkovs'kyy, 2013; Prihodko, 2009; Vakaliuk et al., 2020). The transition from the first-stage aids to the last-stage ones is characterized by two trends. On one hand, the trainee's experience becomes more relevant to the real-world use experience. On the other hand, expenditure for material resources and time per one trainee increases, as well. The reasons are manifold:

- a vehicle and, to a lesser extent, a simulator are expensive to obtain and maintain;

- exploiting vehicles is resource-expensive;

- each vehicle or simulator is able to accommodate a single trainee only and, thus, have very low throughput: each trainee has to enter and leave it one by one.

The above hierarchy is aimed to balance the quality and cost of training, which is to provide the best training for a given budget, by partial replacement of more expensive aids with the less expensive ones. The stated aim is actually achieved.

3 STATEMENT OF PROBLEMS

Nevertheless, the analysis of teaching experience collected in the Institute reveals that the reached balance is still suboptimal.

The first identified deficiency is the extensive use of simulators just as advanced visual aids, when they act simply as 1:1 scale models. Their purpose here is just familiarizing the trainees, who are already taught with textbooks, posters, videos, with the actual appearance of the vehicle cabin (location of controls, indicators, handles etc.). "Familiarizing" here means establishing the connection between the remembered flat two-dimensional pictures of the cabin with its actual spatial three-dimensional appearance and working out the head, arms, hands movements needed to activate the learned controls. This fact leads to the next problems:

- Trainees are able to occupy the simulator one by one only, extending the duration of the class (i.e. the throughput is very low).

- The time available for using the simulator at its full capacity for developing skills by other trainees is, thus, reduced.

- In education establishments, which do not possess a simulator, the trainees are unable to receive this kind of training.

Let us consider a simple example. In a group of 15 trainees and one teacher during a 75 minutes class each person will receive just 5 minutes of experiencing the simulator in the best case (i.e. no preliminary instruction is needed, entering and leaving the cabin occur rapidly etc.). Importantly, the teacher is focused on the single trainee sitting in the cabin and, thus, cannot perform teaching with the rest of the group. Simultaneous utilization of 3–4 simulators may improve the situation but requires corresponding expenses. The reason of such unpractical use of simulators is the absence of other teaching aids, which can be employed instead. In other words, there is a pronounced gap between the first and second hierarchy positions, which is forcedly filled by simulators. It is illustrated in figure 1 where the particular sensational features provided by the discussed teaching aids are shown (Barkatov et al., 2020).

In the described situation only the two basic sensational features of simulators are used out of four that is evidently suboptimal.

The second identified deficiency is while the basic teaching aids (posters and videos) are generally available at present, their abundance is still limited, and technical level often does not meet the standards of

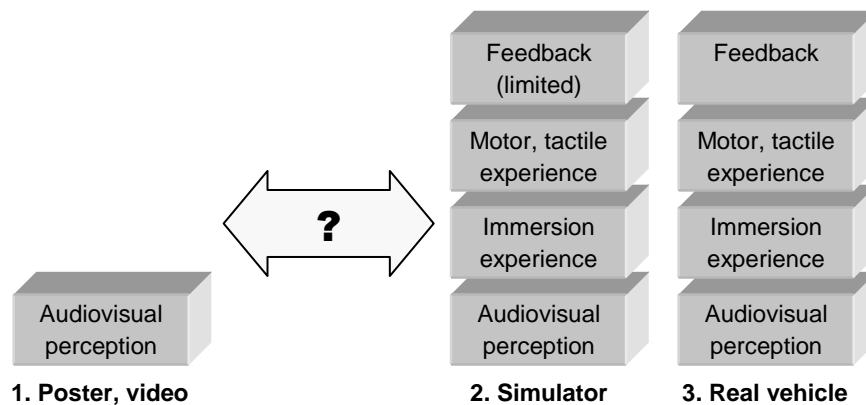|		
	Feedback (limited)	Feedback
	Motor, tactile experience	Motor, tactile experience
	Immersion experience	Immersion experience
Audiovisual perception	Audiovisual perception	Audiovisual perception
1. Poster, video	**2. Simulator**	**3. Real vehicle**

Figure 1: Sensational features provided by the teaching aids in the accepted hierarchy. The complexity and cost of implementation increase top to bottom and left to right. The question mark represents the gap.

modern technology. Videos and animations are valuable means for teaching technical disciplines, which study the structure and functioning of mechanisms and systems. If the former is relatively easy to learn by means of static posters, drawings, diagrams, the latter implies understanding some processes occurring in time and, thus, demands animated visualizations for effective learning. The same is true for studying exploitation of devices, including vehicles, where the object to learn is the procedure (sequence of actions) that must be performed by operator (trainee) to get some result. Importantly, the role of such aids strongly increases in conditions of distance learning when the access of trainees to simulators may be limited. Therefore, the problem of improving their quality and abundance deserved thorough attention.

To create a teaching video about vehicle one needs corresponding visual content, which at present is obtained in either of two ways:

1. Manual drawing a flat or three-dimensional (3D) model of the vehicle from scratch using specialized graphics or engineering software (3D Studio MAX, SolidWorks, AutoCAD etc.), with further animating it.

2. Recording the video of performing operations on a real vehicle using camera.

Unfortunately, both ways are associated with significant difficulties, which limit their application in practice:

- The first way is very labor-intensive. It requires having highly detailed information about the vehicle (dimensions and appearance of its elements). Further, the model prepared in such a way looks noticeably idealized compared with the appearance of the real vehicle. Also, rather high skills are required for creation.

- For the second way, video recording in confined premises like vehicle cabins is difficult and requires appropriate skills and equipment. Moreover, the collected video material cannot be re-used: each sequence of operations in vehicle must be recorded individually. In total these factors make the process time-consuming and labor-intensive, too.

Summarizing, the available range of teaching aids is markedly incomplete, and their creation (posters, videos) or use (simulators) is connected with severe difficulties. This reduces the quality of teaching vehicle-related subjects. The goal of our work is to introduce new teaching aids in order to increase the stated quality.

4 OVERVIEW OF USED TECHNOLOGIES

We propose a collection of teaching aids built around 360° photographic panoramas possibly connected with H5P framework or virtual reality (VR) glasses. In this chapter we shortly summarize these technologies.

360° panorama (also called spherical or 3D panorama) is an image that covers and contains the full horizontal and vertical field of view around a fixed point. It may be either artificial (i.e. drawn manually or computer-generated) or photographic. The photographic ones are created by processing a number of ordinary photographs (each having field of view less than 180°) shot from the same position to all the directions around (Wikipedia, 2020; Grinev, 2019). The principle is shown in figure 2. Specialized software is used for this sake, which generates smooth and con-

tinuous transitions between neighboring shots. Unlike ordinary images, 360° panoramas obviously cannot be viewed as a whole without slicing, therefore, when viewed on displays they are scrolled to the position of interest using computer mouse or other input device. If the target comprises of several sections then an individual panorama should be shot and fabricated for each of them. The user has to switch between them at viewing. At present, they are mostly used for advertisement and entertaining purposes, however, some educational use is also made (e.g., panoramas of museum interiors) (Authentic Ukraine, 2020).

Figure 2: The principle of composing a 360° photographic panorama. The camera is located in the center of the field of view. A single photograph shot is shown explicitly, while for the rest only borders are shown.

H5P (acronym of HTML5 Package) is a framework allowing users create and demonstrate multifarious interactive multimedia content, such as quizzes, interactive videos and presentations etc. The framework is designed such that its use is simple and does not demand special training in information technologies. It is based on a set of Web-related technologies, hence, the content can be created and viewed using any modern Web browser without the need of additional software. Further, it is well-integrated with learning management systems providing the opportunity to enrich distance courses by incorporating interactive content (Scherbyna, 2016).

Virtual reality is a system designed to create the effect of the person's presence in some environment, either having a real counterpart or missing it, by specific affecting their sensors (eyes, hears, skin etc.) via special equipment and software. This effect is usually called "immersion" in the literature. The central component of the equipment is a head-mounted display (called VR glasses), which form the person's field of view by displaying the picture that is provided by VR software. The most important feature of the glasses is interactivity: the movements of the person's head are monitored, transferred to the software and processed

by it for the sake of updating the image in accordance with the new direction of the head (Singh and Singh, 2017). This turns a passive spectator into an active viewer who is able to look around.

In general, the possibilities of utilizing VR in teaching various subjects have been actively discussed for several decades, and different software and hardware solutions were proposed. Mostly, the fields where practical study involves large hazard or expenses were worked out, for example, medicine (Satava, 1993; Rowe and Cohen, 2002; Gallagher and Cates, 2004), technology and fire safety (Ren et al., 2006; Ooi et al., 2019; Zhao and Lucas, 2015; Sampaio et al., 2010; Wang et al., 2018), driving (Bayarri et al., 1996; Kang et al., 2004). At present, it became an accepted aid, particularly, in medicine and military training (Bhagat et al., 2016; Lele, 2013), while in other fields its usefulness is still discussed. For detailed reviews of the place of VR in education, the reader is referred to subject papers (Wang et al., 2018; Lavrentieva et al., 2020; He et al., 2017; Pantelidis, 2009; Osipova et al., 2019; Kramarenko et al., 2020).

5 PROPOSED SOLUTIONS

Basing on a above stated technologies we propose a collection of teaching aids, which we think fills the identified deficiencies well. It is represented in figure 3. Now we will discuss each aid individually.

5.1 Teaching Video

Yet, firstly we describe the possible application of 360° panoramas for making traditional teaching videos. We argue that they can readily serve as a source of visual content for this sake, hence eliminating several related difficulties (see chapter 3):

- Fabricating a photographic panorama is much less labor-intensive and time-consuming than drawing a high-quality poster or 3D model because it does not involve manual reconstruction of the vehicle appearance from scratch. Instead, making a series of photographs is a routine process, and composing the panorama is almost completely automated by software.

- In contrast to recording videos, less skills and simpler equipment are needed for photography. Further, a panorama contains complete information about appearance of the vehicle or its cabin. Therefore, once manufactured, it can be repeatedly used to make a video on any procedure involving this vehicle.
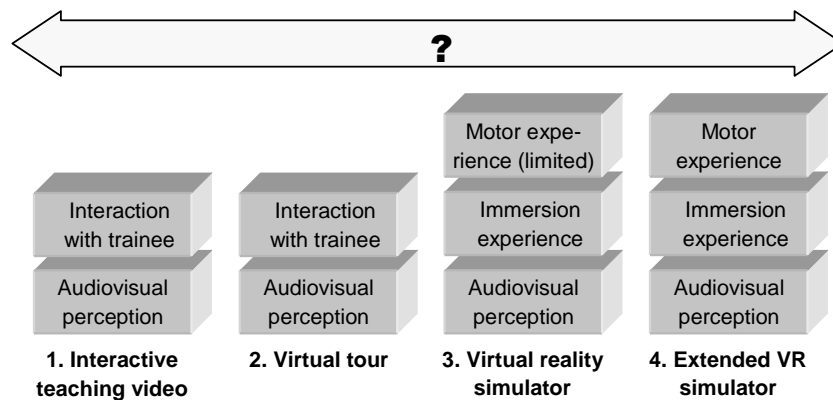
Figure 3: Sensational features provided by the collection of proposed teaching aids, which fill the gap (represented as the question mark).

We propose the following algorithm of making videos basing on 360° panoramas:

- Display the needed panorama on the computer screen.

- Start screen capture together with sound recording from microphone using the corresponding software.

- Consider the first action of the chosen procedure.

- Scroll the panorama to show the view corresponding to the current action.

- Point, which control has to be activated or which indicator should be noticed, by drawing remarks on the screen using corresponding software.

- Voice the performed action and accompanying commentaries.

- Repeat steps 4–6 for the next action until the procedure is finished.

- Stop screen capture.

Among others, we made a teaching video on procedure "Preparation to starting-up and starting-up of the engine" using 360° panorama of BTR-4E shot by us previously. It describes the sequence of 19 actions that trainee in the role of driver has to perform.

5.2 Interactive Video Lesson

As far as 360° panoramas facilitate making traditional teaching videos, they as well assist making the H5P interactive video lessons. The feature of this kind of multimedia content is that it allows incorporating various interactive elements, such as appearing explanations, images, tables, bookmarks, links. During watching H5P interactive video lesson, the user visually and audibly receives information about the procedure they needs to perform. Various test tasks can be added, as well. At a certain point, the video stops playing, and Moodle expects the trainee to perform some action within this video. The playback will continue once the trainee selects the correct action.

The main advantage of this interactive approach is that the trainee takes an active part in the lesson instead of being a passive spectator, which forces them to be more attentive and focused during watching. Importantly, fabrication of such lessons is rather noncomplicated and does not require additional software (they are developed in a Web browser). Such videos can be integrated easily into courses created within Moodle learning management system (Polhun et al., 2021).

Based on the previously mentioned panorama-based teaching video (chapter 5.1) we have made an interactive video lesson, which was then integrated into the distance course "Structure and exploitation basics of BTR-4E". The course is published on the Institute's Moodle platform (dl.khpi.edu.ua, 2020). The next interactivity was added: algorithm of actions in text format, the values shown by indicators during procedure, labels indicating the location of the main devices and controls of the BTR, control questions the trainee has to answer.

5.3 Virtual Tour

Apart from using just as a source of visual content for making videos, the 360° photographic panoramas themselves are excellent teaching aids that surpass other sorts of multimedia:

- The complete information of the vehicle appearance is structured and collected in a single piece

of multimedia that can be explored in a natural way.

- The exact correspondence between the panorama and actual appearance of vehicle elements makes them recognized easily when a trainee enters the real cabin.

- Smooth and continuous exploration of a panorama creates a solid and coherent image of the vehicle interior or exterior in the trainee's mind.

A 360° panorama that can be interactively viewed (scrolled) is called "virtual tour". Optionally virtual tours include some additional content (texts, multimedia) and links to related panoramas (e.g. those of other rooms in an apartment or sections in a vehicle). Displaying and hiding this content and transition between panoramas is done by activating markers, which are placed at chosen points of the panorama.

Demonstration of virtual tours does not require special software and is done in a Web browser. This appears an essential advantage because allows native integration of the panoramas with Web-based learning management systems, such as Moodle. It is done using H5P framework. For Moodle, teacher firstly has to open Content bank and add a content item of type "Virtual Tour (360)", then upload the fabricated panorama there. After this, the described markers for trainee's interaction with the panorama can be placed. The starting position and direction of the view should be set. We recommend firstly load all the panoramas of the vehicle (each its section, maybe its exterior, as well) and then connect them with transitions by means of placing such markers.

We turned the abovementioned 360° panorama of BTR-4E into a virtual tour and integrated it into the distance course (dl.khpi.edu.ua, 2020). Numerous teaching information was added by means of H5P:

- labels of cabin elements and controls to speed up memorization of their location and main purpose;

- schemes to explain the internals of the cabin elements and their connection and interaction with each other;

- video clips to animate the panorama and show the controls and indicators in action;

- control questions to allow teacher check the memorization of material by trainees.

5.4 Virtual Reality Simulator

Despite the rich opportunities provided by software, the full potential of 360° panoramas may be utilized only if they occupy the whole field of view of a trainee

instead of being viewed on a distant display. Virtual reality is the technology that makes this possible. It allows imitate the presence in a real premise depicted on the panorama and achieve the effect of "immersion". Hence, it becomes advantageous to employ VR glasses for viewing 360° panoramas. The next benefits can be reached:

- The image of the 360° panorama appears completely surrounding the trainee, convincingly imitating staying inside the premise.

- The panorama becomes interactive, i.e. responding to the look-up movements of the trainee's head.

Also, the trainee becomes able to perform movements of arms and hands in order to imitate using controls seen in the field of view. Although the former are not visible in VR glasses (without involving additional elaborate VR equipment), this is still useful and provides correct (through incomplete) motor experience because the location of controls in the field of view displayed by VR glasses is the same as inside the vehicle cabin. This feature even more distinguishes this teaching aid from common visual aids (posters etc.), which are unable to provide reasonable motor experience.

Summarizing, the combination of a 360° panorama and VR glasses is able to provide visual perception plus both immersion and limited motional experiences. Hence, it is located in between posters and simulators in the diagram (figure 1) filling the gap described in chapter 2.

Yet, there are several difficulties arising during practical use of VR at classes.

Firstly, while the teaching aids stated above do not require special software for use, here, a dedicated software must be developed that receives the data about head rotations from VR glasses and performs scrolling the panorama. We solved this problem by means of a collaboration with IT company (chapter 5.6).

Secondly, the teacher is unable to monitor the actions of the trainee because they is unable to see the image on the VR display. Therefore, in order to allow controlling the trainee's actions, a supplementary display is needed, whose purpose is to demonstrate the image that is displayed by VR glasses at the moment.

The third difficulty is the very limited ability of the trainee wearing VR glasses to answer teacher's questions about the image seen (e.g. "indicate the button named X on the control panel"). It is caused by the fact that by default, the environment is interactive just to some extent: it responds to the rotations of the user's head, but the user is unable to affect it in any

other way. To solve this problem, the trainee has to be provided with a separate device called "controller". Its purpose is to receive the user's input and affect the image seen in the VR glasses and, as a result, on the teacher's computer display. For example, the trainee would draw lines and other marks on the displayed panorama, in such a way answering teacher's questions. A simplest controller is computer mouse.

Taking all the above into account, the proposed VR simulator consists of four components, which are depicted in figure 4. It may be implemented using a range of hardware; the authors' choice is stated in chapter 5.6 (Barkatov et al., 2020).

5.5 Extended Virtual Reality Simulator

As it has been mentioned in the previous section, the VR simulator in the present implementation lacks some useful features. Firstly, the trainee does not see their hands, therefore, the arms movements imitating reaching vehicle controls has to be made blindly. Secondly, there is no tactile experience: the movements of hands and fingers imitating activating vehicle controls are made in empty space that does not provide tactile feedback (the sense of touching a solid object, the resistance force appearing during its activation). Introducing there features (at least, approximate) can improve the immersion effect.

At present, there is a technical mean available that can achieve this goal, namely, VR gloves. This device connects to the VR glasses and performs two-side data exchange. Firstly, the data about current location in space and pose of the hand is collected from sensors and transmitted to the VR glasses. VR software can process this data and draw a 3D model of hand in the correct pose and location with respect to the virtual environment. So that, VR gloves can serve as a controller allowing user point some places of the displayed panorama or perform hands and fingers movements to answer teacher's questions. Secondly, the VR software continuously checks the contacts between the 3D model of hand and the virtual environment; if any, it sends the information about the location and character of the contact to VR gloves. The gloves process this data and activate matching vibrating motors to make the user feeling virtual objects. In total, these features help to correctly perform and remember complex operations, even if they require fine motor skills. This is rather actual for vehicle-related subjects because the panels in vehicle cabins or in mounted equipment are full of diverse buttons, toggles, levers, and other controls.

Yet, there are obstacles hindering wide application of this aid. The functionality for proper display-ing the 3D model of hands must be implemented in the used VR software, which is a non-trivial problem. Moreover, the cost of VR gloves is considerable at present. Still, we expect that the advances in the field will facilitate solving these difficulties and make this aid much more feasible in the near future.

5.6 Details of Implementation of VR Simulator

For the implementation of the software part, a tight collaboration between the Institute and IT company "Innovative Distance Learning Systems Limited" was established. The Company developed the viewing software, and the experts of the Company performed photographing the interiors and exteriors of vehicles, fabrication of 360° panoramas, and loading them to the viewing software. The Institute took part in developing the content, carried out approbation, and developed methods for the most efficient application of the product in teaching.

The hardware part was chosen in accordance with the following considerations.

The VR glasses are of two kinds. The first kind comprises a built-in display; such glasses must by connected to a source of video signal, which is usually a computer running VR software. The second kind of glasses is called "VR boxes". There, the role of display is played by a smartphone, which has to be installed (reversibly) into the VR box. In this case, the source of video signal is the same smartphone, which runs VR software.

The teacher's display must be connected either to the computer that generates the image for VR glasses of the first kind, or to the supplementary computer that receives the image from the smartphone installed in VR glasses of the second kind.

The simplest kind of controller is computer mouse: when connected, a cursor is shown on the image, and the trainee is able to move it and set to the needed position (e.g., to the position, at which some control is seen at the moment).

Taking this into account we used the next hardware in our implementation (figure 5):

- a smartphone running Android operating system where VR software is installed and 360° panoramas are uploaded;

- a VR box because it does not require a computer to work, is much cheaper than VR glasses, and still provides the ability to view 360° panoramas;

- a wireless computer mouse as a controller because it is a common and inexpensive device requiring no adaptation for trainees;
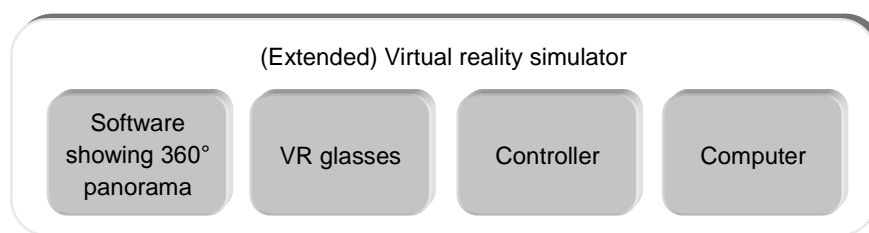
Figure 4: Composition of the proposed virtual reality simulator.

- a laptop running Windows 10 operating system because the needed configuration is relatively simple and the image from VR glasses may be received wirelessly via Miracast technology.
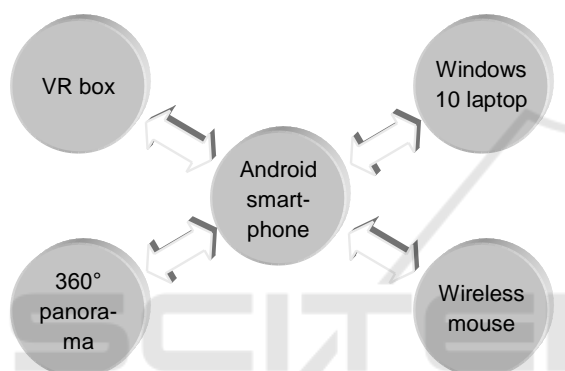

Figure 5: Authors' choice for the hardware implementation of proposed virtual reality simulator.

Considering the extended VR simulator that includes VR gloves as a controller instead of computer mouse, we note that the gloves must meet several requirements to provide the best immersion experience during training:

- complete finger tracking;
- usage of moisture-resistant material;
- tracking the shoulder joints and wrists;
- wireless implementation with low latency;
- vibrating motors for tactile feedback.

Finally, to maximize the immersion experience, the VR software should accompany all trainee's actions on switching on/off the controls by accurate sounds.

5.7 Application in Teaching

The 360° photographic panoramas are well-suited for demonstrating confined premises where all the points of interest (labels, controls, indicators etc.) are located at a similar distance from the viewer. Actually,

this is a case for most vehicle cabins and portable equipment, transported by vehicles (e.g. portable chemical laboratories). Therefore, the aid is most suitable for teaching subjects considering the above things.

Considering the financial side, the total price of the aid is very limited (hundred to thousand times less than a price of a single simulator), which makes feasible for educational establishments to obtain the aid. Moreover, the price makes readily possible equipping specialized classes for groups of 10–20 trainees. This option proportionally increases the time a trainee spends in the teaching aid and, thus, further improves teaching quality.

Importantly, the first three aids (360° panorama-based traditional and interactive videos, virtual tours) are ready for use at distance learning, as well. Moreover, we expect that in perspective VR glasses will become even more affordable, and it would be possible for trainees to equip themselves with proposed VR simulators and attend the corresponding classes distantly. This would improve their learning experience even more.

Summarizing, 360° photographic panoramas appear as a multifunctional content that can be turned into a range of teaching aids of different character.

5.8 Test of Effectiveness

In order to test the efficiency of the proposed aids, a teaching experiment was carried out at the Institute. The points #1 "Location and operation rules of controls and indicators" and #2 "Preparation of the vehicle to engine starting-up and movement" of the practice lesson "Training at simulators on preparatory exercise #1" belonging to the credit module "Driving basics" of the subject "Basics of driving combat vehicles" were chosen. The exercise #1 in this module is "Preparation to starting-up and starting-up of the engine" (further called "the exercise"), its procedure contains 19 steps.

The experimental class was held at an experimental multifunctional room. 360° panorama-based teaching videos, virtual tours, and VR simulators

were employed. For comparison of efficiency, the reference class on the same lesson was held in a traditional way using common teaching aids (posters, conventional simulators).

Both classes started with learning the general structure of the BTR-4E transporter, its cabins, controls, and exploitation basics. The trainees were provided with the general information about the purpose of the control cabin and the driver operating procedure by means of either posters and textbooks (reference group) or distance course "Structure and exploitation basics of BTR-4E" (experimental group) containing 360° panorama-based teaching videos and virtual tours (dl.khpi.edu.ua, 2020).

Then, the training was continued with the help of either a conventional simulator (in the reference group) or the proposed teaching aid further called "a VR simulator of the driver cabin" (in the experimental group). In the latter case, the procedure was as follows. The teacher divided the group to pairs, and in each pair trainees were assigned with #1 and #2. Then, the following tasks were specified to #1 and #2:

Actions of #1: Help #2 to wear a VR simulator and take a controller. Read the text of the exercise procedure step by step making pauses after each step to allow #2 find the needed control. Check the correctness of #2's actions by watching the laptop, do corresponding notes and write down the results of training into the control sheet.

Actions of #2: Wear a VR simulator and take a controller, repeat the steps read by #1, find the needed control and point it with the controller. Then, pronounce each step of the procedure by memory, find the needed control and point it with the controller.

When the actions were completed the trainees #1 and #2 exchanged their roles.

The success of teaching during the experimental and reference classes was assessed by the results of the next class, when both groups of trainees had to execute the exercise at a conventional BTR-4E simulator. This class has been carried out identically with both groups. The main results are as follows.

The marks for completing the exercise are summarized in table 2. Here, the mark is determined by the consumed time: "excellent", "good", "satisfactory" corresponds to no longer than 1 min 30 sec, 2 min, 2 min 30 sec, respectively. It is seen that both groups have similar distribution of marks that indicates they received equivalent training. This proves that the collection of proposed teaching aids is able to successfully augment the traditional teaching aids and replace full-size simulators in the task of familiarizing trainees with vehicle cabin.

Further, the occupation of the conventional sim-

Table 2: The success rates of the two groups of trainees.

	Control group	Experimental group
Total trainees	25	25
"Excellent" marks	10 (40%)	11 (44%)
"Good" marks	8 (32%)	6 (24%)
"Satisfactory" marks	7 (28%)	8 (32%)
"Unsatisfactory" marks	—	—

ulator by the experimental group was 4 times lower than by the reference one. Hence, application of the proposed aid allows free substantial amount of the simulator time, which then can be allocated to other classes, which employ full range of its capabilities.

6 CONCLUSIONS

Deficiencies in the available range of teaching aids for vehicle-related subjects, which decrease the teaching quality of the subjects, were identified. Firstly, it is desirable to rise the amount, quality, and technical level of such basic teaching aids as teaching videos. Secondly, there is a high demand for a teaching aid that possesses such feature of the simulators as immersion but is less expensive. Both these deficiencies are proposed to fill by means of an introduced collection of new teaching aids based on 360° photographic panoramas.

Considering the first deficiency, the panoramas can readily serve as a content for making teaching videos, including the H5P interactive ones. Importantly, the process of fabrication and the needed equipment are much simpler than those for traditional posters and videos. In addition, the panoramas themselves act as an interactive teaching aid with functionality inaccessible for traditional posters, drawings, videos that can be naturally integrated into learning management systems like Moodle.

The second deficiency is solved by a teaching aid constituting the 360° photographic panorama viewed in virtual reality glasses. Its main feature is the possibility to provide visual sensation, immersion and motor experiences, which are approaching to the provided by conventional simulators. At the same time, the equipment is rather affordable to obtain by educational establishments, and its usage is straightforward and does not demand special skills.

The efficiency of the aids was proved by a teaching experiment that showed they can serve as an alternative to conventional posters and simulators on the stage of trainee's familiarizing with vehicle cabin appearance.

Summarizing, we think the proposed collection of

aids may significantly improve the technology level and cost-efficiency balance of teaching the subjects where vehicles or mobile equipment are considered, and may receive wide application in civil and military education establishments, emergency and military units, enterprises using special equipment. At present, we have completed the 360° photographic panoramas of a series of armored (BM "Oplot", BMP-2, BTR-4E) and emergency (fire engine) vehicles.

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