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Design of a Research and Training Platform for Operating Portable Chainsaws Using Virtual Reality Technology

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Abstract. The logging industry belongs to one of the industrial processing branches with the greatest risk of accidents at work. Unfortunately, such situations often result in serious injuries and even the deaths of employees. In most cases, the casualties are people who are badly trained and inexperienced, with a short employment history. One solution to avoid these tragedies is to support workers employed in this industry with training applications. This paper presents a description of a research and training platform for operating portable chainsaws using virtual reality (VR) technology. The platform simulates phenomena occurring while working with a chainsaw, such as falling tree parts, the occurrence of chips and characteristic sound effects. The study used the HTC Vive Pro set and a dummy chainsaw with an electric module, thanks to which the application lets you control a virtual chainsaw using a real life device tracked by a system for mapping objects in space.

For the purpose of this work, a series of 32 tests were conducted with 16 subjects and conclusions were drawn on the basis of test reports and surveys, in which the subjects expressed their opinions about the course of events in the platform application.
Keywords: virtual reality, VR, research and training platform, chainsaw, forestry, work safety

1. INTRODUCTION

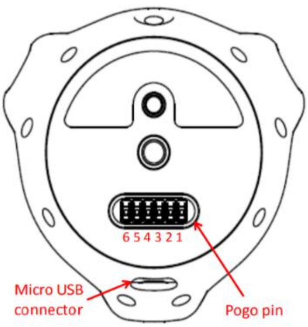
Virtual Reality (VR) is being increasingly applied in many industries, such as medicine, military, education, entertainment, marketing and architecture. This technology is about creating digital reality that seems real for the user who enters it. Thanks to this, it is possible to easily recreate conditions that are otherwise impossible from a logistical point of view and also those that are prohibitively expensive or dangerous.

One of the industries in which there is considerable danger whilst at work is forestry. According to the Central Statistical Office (GUS) data from January-September 2019, 685 people working in the agriculture, forestry, hunting and fishing industries were injured in accidents at work, including 8 serious and 6 fatal injuries. This is 3.7 people injured or killed per 1,000 people working in these industries. This statistic is one of the highest among the industrial processing branches. The most severe injuries suffered at work included collision with/hitting a stationary object (approximately 32%), getting hit by a moving object (approximately 21%) and contact with a sharp, rough or coarse object (approximately 18%). The main cause of accidents at work was the employee's inappropriate behaviour (about 60%) [1]. According to the 2017 Report of the National Labour Inspectorate on work safety in forestry, the inspectors investigated 128 accidents in the logging industry between 2014-2017, in which 133 people were injured, including 45 deaths and 37 serious injuries. The main cause of the injuries was getting hit by a falling branch or tree trunk due to not observing the basic safety requirements, mainly by inexperienced employees with a short employment history. According to the same report, in every third company employees did not receive initial or systematic training in occupational safety [2].

Nowadays, thanks to the implementation of technological solutions, potential accidents at work are being increasingly prevented. An example of the use of modern technology is the creation of training platforms in the field of work safety with the proper use of mechanical devices. The subject of this paper is a description of a research and training application project for operating portable chainsaws in virtual reality. The platform is designed to train a person with no experience in the art of tree felling with a chainsaw. Thanks to the use of VR technology during the training, the risk of injury is eliminated, in particular getting hit by a falling piece of wood or by physical contact with the sharp moving parts of the chainsaw.

2. THE APPLIED TECHNOLOGY

The research and training platform was developed for the HTC Vive Pro set. It includes VR goggles, a controller and a tracker. The goggles are equipped with a display of a resolution of 2880x1600 pixels and a field of view of 110 degrees. They have the option of adjusting the distance between the lenses focusing the image from the display, thanks to which the headset can be adapted to most face shapes. Additional elements of the device are headphones, microphone, accelerometer, gyroscope and sensors for tracking position and rotation in the SteamVR system. The goggles have an adapter that enables wireless communication with a computer. The set also includes a wireless controller equipped with 24 tracking sensors in the SteamVR system, a multi-functional joystick, a two-stage trigger button and several other buttons, as well as a battery and a vibration module. An additional feature of the set is a wireless tracker that serves as a motion tracking sensor. The device has 6 pins (so-called pogo pins) transferring the data between the controller and the computer. Each pin transfers different data. Figure 1 shows the rear part of the tracker and the function descriptions of the individual pins of the device.



pin no.	function
1	digital output
2	grounding (GND)
3	digital input / power supply
4	digital input
5	digital input
6	digital input

Fig. 1. The back of the tracker of the HTC Vive Pro set with a description of individual pin functions [3]

The research and training platform application is based on the Unity 3D engine. This is one of the most popular development environments for creating two-dimensional and three-dimensional computer games, simulators, visualisations and animations. It owes its universality to being multi-platform – thanks to the use of compiler directives, applications made in Unity can be developed for any operating system. In addition, the engine cooperates with most of the systems supporting VR/AR technology. They include, among others, Oculus Rift, Google Cardboard, SteamVR, Playstation VR and Gear VR [4].

The cooperation of the HTC Vive Pro set and Unity 3D takes place thanks to the SteamVR system. The devices are tracked with the help of base stations called lighthouses. These stations collect data from sensors placed on the devices and are then processed by SteamVR.

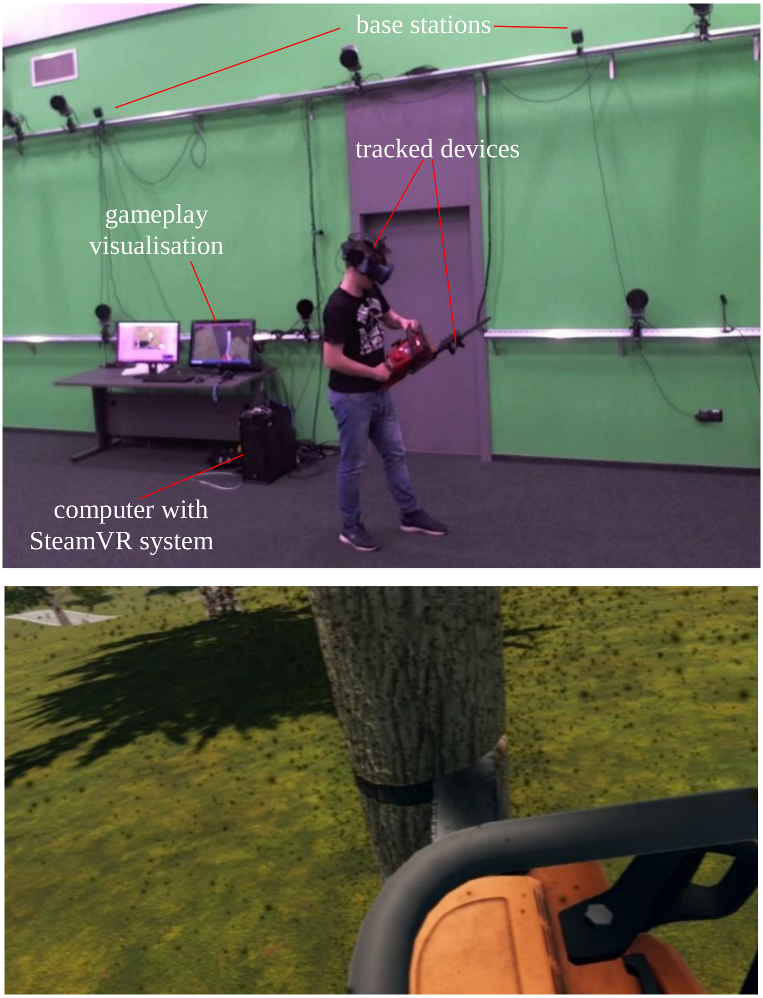


Fig. 2. The concept of device tracking by base stations using the SteamVR system and the view in goggles

Using them, you can determine the current positions and rotation of tracked devices. Figure 2 presents the concept of VR set tracking devices using base stations by means of the SteamVR system and the view from the VR goggles from the operator's point of view. Data from the SteamVR system in Unity are processed using the XR Toolkit. This plug-in supports most devices using virtual reality (VR), mixed reality (MR) and augmented reality (AR) technology.

The position and rotation data from the HTC Vive Pro set are collected as floating point data. Controller button and tracker pin status are registered as Boolean logical variables.

3. RESEARCH AND TRAINING APPLICATION

The purpose of the platform developed, in addition to its training function, is to conduct a series of tests on users and to draw conclusions based on reports from the conducted research. One of the aspects analysed is the comparison of the use of a controller as an equivalent of a chainsaw and a real chainsaw as a dummy device, tracked in VR technology. In order for a chainsaw to be tracked by the SteamVR system, it has a wireless tracker and accelerator button status data converter installed. In chainsaws, this button is used to adjust the engine speed during operation. In the dummy device there is a potentiometer measuring the change in resistance depending on the state of the chainsaw accelerator button and an STM32F1 family 32-bit microcontroller with an ARM Cortex-M3 core that processes this data into digital form. Information on the chainsaw button status is provided to tracker pins and then processed in Unity as the status of the simulated VR controller buttons. In the dummy, the system is powered by a powerbank with a USB connector.

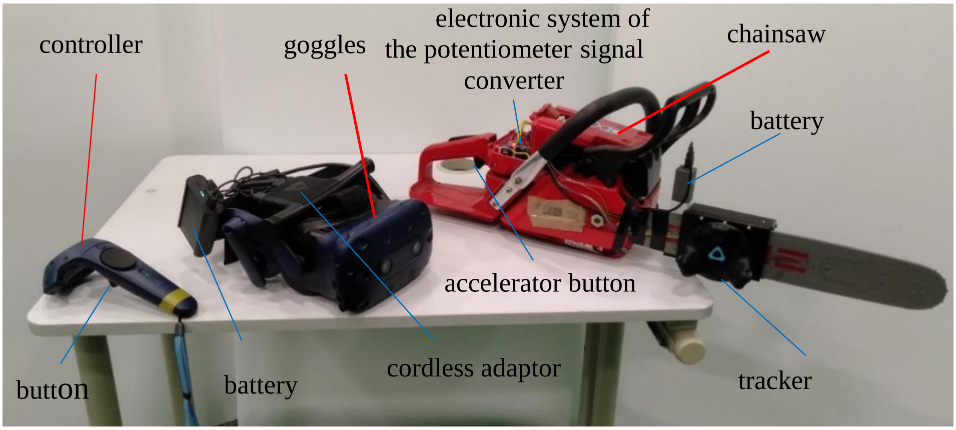


Fig. 3. Applied equipment with a description of individual parts

A set of all the devices used for the study is presented in Figure 3. In order to take the picture, the chainsaw housing was unscrewed and removed, so that the described electronic system is visible. The study consists in cutting successive tree parts. In a single task, the indicated element should be cut (referred to as a connector in the project). This element is located in a commonly-cut area of the tree to be processed. Usually it is a part between a branch and a thicker branch or in the centre of a larger branch.

Figure 4 shows an example of a tree with parts marked for cutting and a visualisation of a virtual chainsaw.

Fig. 4. Tree with marked parts for cutting and a virtual chainsaw

Unfortunately, due to the lack of resistance and lack of detection of a physical contact between the virtual chainsaw and the tree, it is necessary to simulate a situation in which the user feels the need to increase the pressure of the saw on the part cut. For this purpose, correct cutting with the chainsaw takes place only when a part of the virtual chainsaw meets the connector and thus does not contact the parts that are not allowed to be cut. This situation requires the user to tighten their muscles and make appropriate movements during the test, which is intended to give the impression that the chainsaw has made contact with another physical object. Contact detection takes place thanks to the physics system in Unity, which allows for the interaction of objects simulating behaviour in the real world. The object whose contact should be detected by the physics system needs a component that defines the shape of the object that is to interact with other objects; the so-called collider.

There are several types of this component corresponding to the typical shapes of solids: a box (box collider), a sphere (a sphere collider) and a capsule (capsule collider). There is also a type of collider whose shape is similar to the shape of a given object (mesh collider).

However, the mesh collider has a big disadvantage – it uses more memory resources to detect contacts than the colliders of typical shapes. In the application, the shape of cylinder-like connectors is approximated by a few box colliders.

Contact detection events, or "one object entering another", are detected in Unity with the *OnTriggerEnter* method, the parameter of which is contact with the detected object.

In contrast, the *OnTriggerExit* method was used to detect the end of the contact, i.e. "one object exiting another". Figure 5 shows the situation of a virtual chainsaw contact with parts of a cut tree.

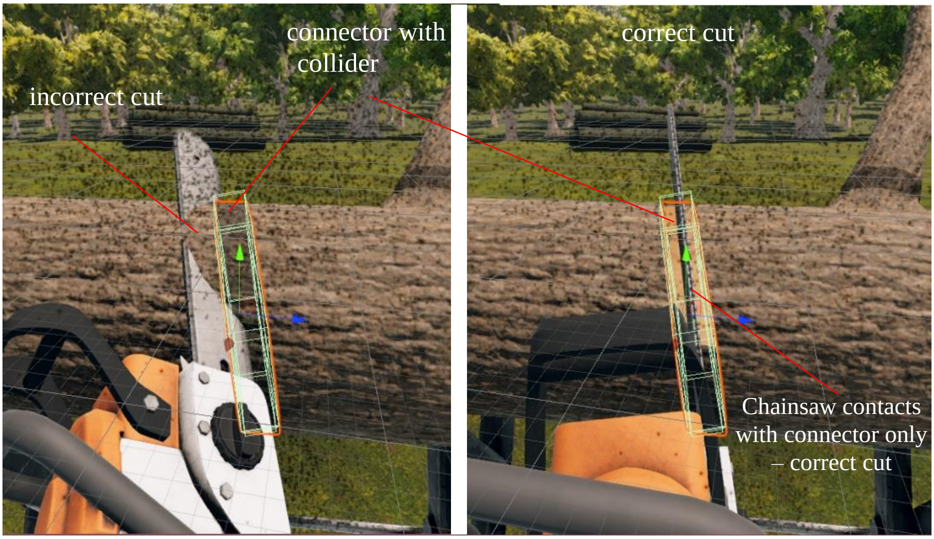


Fig. 5. Contact of the virtual chainsaw with elements of the cut tree. Left: bad, prohibited cut – contact with branches. On the right: good, permitted cut – no contact with other tree parts

On the left, you can see a situation where cutting is prohibited due to contact with a branch that is not permitted to be cut. On the right, the connector is permitted to be cut as the chainsaw only interferes with this part of the tree.

4. RESEARCH RESULTS AND CONCLUSIONS

As part of the research and training platform testing, 32 tests were carried out on 16 subjects in the 20-30 years of age group, 69% of whom were men.

Most of the respondents (81%) had contact with virtual reality technology in the past and everyone had watched a 3D (augmented reality) film in the cinema. 69% of people had used chainsaws for personal or professional purposes.

A single test involved the cutting of virtual tree branches using the selected control mode. Each person tested performed the same task twice – first with the controller and then with the dummy chainsaw.

During the simulation, the task completion time and efficiency were measured. The efficiency was determined on the basis of the percentage of contacts of the virtual chainsaw with parts that were not permitted for cutting. Before and after the simulation, the tester was asked to fill in a questionnaire in which descriptive statistics were provided and questions were answered to assess the usefulness of the system (SUS) [5], the level of simulator sickness symptoms (SSQ) [6], the level of spatial presence (SPQ) [7], the level of technology acceptance (TAM) [8], task load (NASA-TLX) [9] and the level of stress and anxiety (DSSQ) [10]. In addition, each of the respondents was asked to specify in which control mode they performed their task best and why they thought so.

Based on the reports generated during the study, the average time of completing a single task with the controller was 43% lower than with a dummy chainsaw. Despite the much longer time to complete a single task in the dummy chainsaw mode, the average efficiency was 61% higher than in the controller mode. These results also confirm the opinions of the surveyed testers, most of whom believed that they were better at controlling a dummy chainsaw. Percentage of responses regarding the control mode during the simulator test is shown in Figure 6.

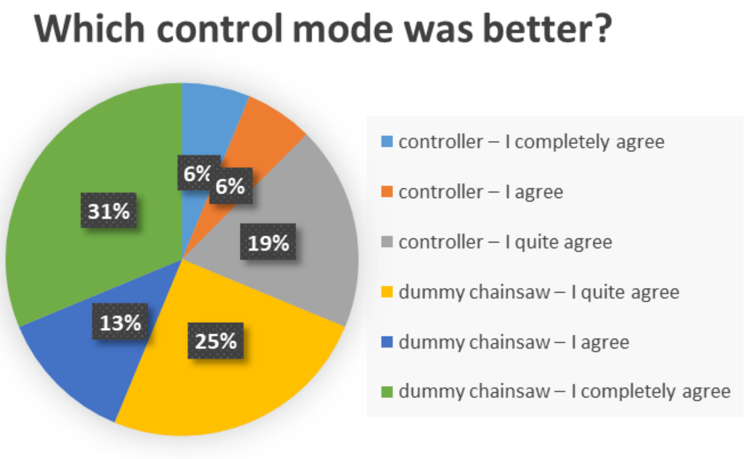


Fig. 6. Percentage of subject responses regarding the control mode in the simulator.

It is also worth adding that most of the people who considered the controller mode to be better were female. Due to the heavy weight of the device, most of the women were unable to perform some tasks with a dummy chainsaw, in particular those in which the tree had to be cut horizontally to the floor. The men performed all the tasks in the simulator. Most of them considered the dummy chainsaw control mode to be better, giving the greater versatility of the device and its greater weight as the main reasons.

Thanks to these, they could hit the tree connectors allowed for cutting with higher accuracy. In many cases the platform operators tried to hold the controller with both hands, just like holding an actual chainsaw, thus eliminating the vibrations of one-handed use and increasing the precision of the task performed.

This shows the importance of the need to use dummies resembling the simulated devices in similar applications.

There are plans to further develop the platform in the future. One idea is to use advanced mechatronic devices to introduce force feedback into the simulation. If applied, it will increase the impression that the simulation is real – the operator of the virtual chainsaw will not only see and hear the phenomena occurring in wood processing, but will also feel physical resistance when the chainsaw comes into contact with other virtual objects.

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Projekt platformy badawczo-szkoleniowej do obsługi przenośnych pilarek łańcuchowych z zastosowaniem technologii wirtualnej rzeczywistości

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Streszczenie. Branża pozyskiwania drewna należy do jednej z sekcji przetwórstwa przemysłowego, w której występuje największe niebezpieczeństwo wypadku podczas pracy. Niestety takie sytuacje często skutkują ciężkimi obrażeniami, a nawet śmiercią pracownika. W większości przypadków szkodę odnoszą osoby źle przeszkolone oraz niedoświadczone, o krótkim stażu pracy. Jednym z rozwiązań uniknięcia tych tragedii jest wspomaganie pracowników tej branży za pomocą aplikacji szkoleniowych. W niniejszym artykule przedstawiono opis platformy badawczo-szkoleniowej do obsługi przenośnych pilarek łańcuchowych z zastosowaniem technologii wirtualnej rzeczywistości (VR). W platformie symulowane są zjawiska mające miejsce podczas pracy z pilarką, takie jak: opadające fragmenty drzewa, występowanie wiórów, charakterystyczne efekty dźwiękowe. W badaniu użyto zestaw HTC Vive Pro oraz atrapy piły mechanicznej z modułem elektrycznym, dzięki czemu w aplikacji można sterować wirtualną pilarką za pomocą rzeczywistego urządzenia śledzonego przez system mapujący obiekty w przestrzeni. Na potrzeby artykułu przeprowadzono serię 32 badań na 16 osobach oraz wyciągnięto wnioski na podstawie raportów z tych badań oraz ankiet z opinią osób badanych o przebiegu wydarzeń w aplikacji platformy.
Słowa kluczowe: rzeczywistość wirtualna, VR, platforma badawczo-szkoleniowa, pilarka łańcuchowa, leśnictwo, bezpieczeństwo pracy