Advanced Immersive Capabilities in Virtual Reality Applications Using IMU Sensors

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Abstract. The rapid development of virtual and augmented reality technologies today takes place in almost all areas of activity. The relevance of the study is due to the modern demand for developers to use the latest technologies in the field of game development. Currently, technology is becoming more popular, ensuring that the player is immersed in virtual reality. One of these technologies is a suit with wearable sensors that track the position of a person in space in real time. However, this technology is quite young, but has already gained popularity due to its extensive use capabilities and combinations with other game gadgets. Therefore, at the moment there is a problem of no examples of application development using this technology. This article demonstrates the possibilities of a suit with wearable sensors when creating an entertainment application.

1. Introduction

VR (virtual reality, virtual reality) is a set of technologies using which you can create an artificial world that does not physically exist, but is felt by the senses in real time in accordance with the laws of physics. Virtual objects and subjects created by technical means influence a person through his sensations: sense of smell, sense of balance and position in space, touch, vision, taste, hearing [3]. Virtual reality systems are devices that more fully mimic interaction with the virtual environment than conventional computer systems by affecting all five sensory organs in a person. There are different types of virtual reality systems that are used in the entertainment and scientific spheres [1]: Augmented (AR) - the virtual reality system does not distort the usual vision of the surrounding world, but only complements it with artificially created elements. Mixed - Here you snap artificially created elements to real elements, which creates a large degree of realism. Virtual (VR) - all elements are the fruits of the fantasy of developers or a simulated program. Virtual space today is the main communication field for different target groups and primarily for young people. VR is used in various fields, such as, for example: education, energy and construction, medicine, industry, business, transport, gaming, tourism, etc [2]. The rapidly growing popularity of VR/AR enables, for example, marketing professionals to leverage new capabilities in integrated marketing communications. Demonstration of products and services through virtual and augmented reality techniques and methods is an effective communication mechanism in different markets [3]. The uniqueness and ease of use of AR and VR technologies, the bright and emotional imagery of the virtual field provide attraction and consumer interest in the product/service. In this article, we will focus only on one of the popular sections of VR/AR - this is game development [4, 5]. The relevance of the work is determined by the modern demand for the use by developers of the latest technologies in the field of game development. Currently, technology is...
becoming more popular, ensuring that the player is immersed in virtual reality. One of these technologies is a suit with wearable sensors that track the position of a person in space in real time [6]. The novelty of the study is that the technology is quite young, but has already gained popularity due to its extensive use capabilities and combinations with other gaming gadgets. Therefore, at the moment there is a problem of no examples of application development using this technology [7,8]. It was decided to demonstrate the capabilities of a suit with wearable sensors when creating an entertainment application. The following scientists made a great contribution to the development of the theory and practice of developing virtual and augmented reality: Herron J., Kelly D., Hoang T. N., Joukhadar Z., Clements T., Vetere F., Bower M., Howe C., McCreedie N., Wang S., Ileyky A.I. M., Elbyaly M.Y., Nabokova, L.S., Turan Z., Meral E., Sahin I.F. and others.

2. Problem statement
As part of the study, we tested the capabilities of a suit with wearer sensors when creating an entertainment application. The study was carried out on the basis of MSTU named after Nosov in the framework of laboratory and practical work. As well as in a real enterprise as a project execution in order to gain experience. Due to the confidentiality of the results of the study, we cannot provide the finished results of the project in this article, but we will consider in detail the process of applying the capabilities of the suit with wearable sensors when creating an entertainment application [9].

3. Theoretical and practical importance
Let's take a closer look. In itself, the technology of tracking an object in space is not new. It is actively used in modern smartphones both for system needs and in various applications. Sensors are small hybrid modules and combine angular velocity, acceleration and magnetic sensors: accelerometer - a sensor that measures angular acceleration; gyroscope - sensor measuring angular velocity around its own axes; magnetometer - sensor measuring magnetic field induction [10, 11]. All sensors are read and transmitted in real time to the computer. Based on the collected data, a special application determines the exact position of a person in space. Thus, a suit from IMU sensors allows you to track all human movements in real time and broadcast them to the application. Apple was the first to introduce into the gyroscope in iPhone 4. After the appearance of sensors, it became possible to answer incoming calls, page e-book, sheet photos, switch music and much more by simply shaking the phone [12]. Along with simple functions, developers created and introduced more sophisticated software into smartphones, such as a tilt and level measurement program. From a technical point of view, the gyroscope is a rather complex device. When developing it, they took as a basis the principle of work of an accelerometer, which is a flask with a spring and a load inside. Weight is fixed on one side of spring, and second side of spring is fixed on damper for damping of oscillation. When the meter is shaken (accelerated), the attached mass moves and stresses the spring. Such fluctuations can be presented as data. If you place three such accelerometers perpendicular, you can get an idea of how the object is located in space. Since it is technically impossible to arrange such a bulky measuring device in a smartphone, the principle of operation was left the same, but the load was replaced by an inert mass, which is located in a very small chip. During acceleration, the position of the inert mass changes and thus the position of the smartphone in space [20] is calculated. The advent of sensors in mobile devices inspired many developers to create innovative projects. Thanks to the accelerometer and horoscope, mobile games have reached a new level, and the degree of player immersion in the gameplay has significantly increased [13, 14]. Over time, the application area of sensors expanded, costumes were created that track the position of a person in space and are used to capture movements. Motion capture technology is also actively used in the gaming industry and in the creation of CGI cartoons. A suit with sensors is worn on a person, and he produces the necessary movements, gets into poses and imitates actions. At this point, information is read from the sensors and sent to the computer, where all the data is consolidated into a single three-dimensional model. Sensors are not only used to create entertainment applications. They are actively used for medical purposes, for example, to help the patient restore motor functions. So the Devirta Ergo 3D application, which works in conjunction with the virtual reality helmet, helps patients restore some household skills. With this application, the patient performs daily duties in
virtual reality. He can brush his teeth, refill his bed, prepare breakfast, carry out general cleaning and much more [15]. When performing these actions, the helmet and special stations read the human movements and transfer them to the application for processing. This information is processed and displayed in the virtual reality helmet. As a result, the application motivates the patient to restore his motor skills by repeatedly repeating simple movements. Let’s take a few examples of costumes from different manufacturers and make a comparative characterization. The following costumes will participate in the comparison: SensoSuit; RokokoSmartsuitPro; Perception Neuron-32 V2. The Senso Suit, due to its versatility, is compact and comfortable to use, sits conveniently on the user, its sensors do not hesitate to move, it is easy to set up and fix and allows you to fully track body movements without the need for complex settings. The Senso Suit positional tracking system kit consists of 15 tracking modules that are worn on the body, arms and legs. Each module is a relatively small box measuring 2.5x2.5 cm. These modules are perfectly attached to the body, legs and hands and do not constrain movements at all. Each module has an IMU sensor inside, as with most products from Senso, and a vibration motor, which provides tactile feedback from what is happening [16, 17].

Specially, for convenience, there is the possibility of connecting the suit to the computer either through a USB cable or via Wi-Fi connection with the option of choice. The suit does not require the use of additional cameras, and SteamVR/Lighthouse (used by HTC in Vive virtual reality helmets) is used as the main movement tracking technology for high accuracy and positioning speed. Due to this, each of the 15 modules has a SteamVR sensor with which you can use any Valve systems and not only (like HTC Vive) to improve body tracking. Also, this positional tracking system has compatibility of the device program code with the common C++, Unreal Engine, Unity and Android engines - with the presence of SDK and open source code for each of them [18]. Rokoko Smartsuit Pro is a high-tech motion capture studio presented in the form of a regular suit. Smartsuit Pro makes the professional mocap system accessible to everyone and expands the capabilities of developers and 3D animators more than ever before. The main advantage of the suit for many specialists is a simple and understandable setting. It is enough to put on a suit, run the software supplied in the kit, calibrate the system slightly and start recording data. It'll take less than five minutes for all the surgery.

Smartsuit Pro is equipped with 19 sensors that track the position in the 9-dof measurement, providing high-quality motion capture. At the same time, the use of the suit does not require the use of any additional parts. The suit allows you to capture the movements of a person anywhere and whenever [19]. Smartsuit Studio software allows you to visualize your data in real time. You can track and modify movements in real time or record them for later use. Smartsuit Studio Software and the presence of plugins for Unity 5, Unreal Engine 4, MotionBuilder will ensure the application runs in all popular development environments and use of recorded movements. Perception Neuron V2 is a motion capture system. The inertial navigation system underlying Perception Neuron V2 is a very cool technology. The IMU board is based on three-axis micromechanical sensors, so the Perception Neuron is controlled using a tiny unit, no more than a sugar cube, which consists of: accelerometer, gyroscope and magnetic tracker. Perception Neuron V2 has an updated ecosystem that will allow owners of both generations of trackers to use tiny sensors weighing 1.2 grams with special straps and a suit to record the movements of the whole body. In Perception Neuron V2, jitter is significantly reduced and it is possible to write an extended data set for a longer time. Perception Neuron V2 received slip-proof belts and reinforced cable fasteners. The sensor mount has also been redesigned for the convenience of the user - now it is easier to put on and remove the sensor. This is not only an impressive evidence of the power of miniaturization, but also an accurate tracking system. When Neuron Perception synchronizes with 32 neurons, the device begins to track the movements of the entire body and create its virtual prototype. You see an incredibly accurate phantom in the game space that will repeat all your movements, from jumping and running to moving your fingers, with a delay of up to 16 ms. Regardless of what function Perception Neuron V2 performs, the motion capture system is a useful tool that should be available to a wide audience. Perception Neuron V2 an interesting product for indie developers, animators and 3D lovers. Comes with Axis Neuron software and C/C++ API with Unity and Unreal Engine support. Consider the comparative characteristics of the costumes presented in Table 1.
Table 1. Comparison of motion capture suits.

|                      | Senso Suit | Rokoko Smartsuit Pro | Perception Neuron-32 V2 |
|----------------------|------------|----------------------|-------------------------|
| Number sensors, pcs. | 15         | 19                   | 32                      |
| SDK                  | Unreal Engine, Unity, Unity 5, Unreal Engine 4, MotionBuilder C/C++ API, Unreal Engine, C++, Android | Unity C/C++ API, Unreal Engine, Unity |
| Connection           | Wi-Fi, USB | Wi-Fi, USB           | Wi-Fi, USB              |
| Feedback             | 15 вибромоторов | –                   | –                       |
| External tracking    | SteamVR, Lighthouse | –                   | –                       |
| Price, RUB           | 84 000     | 295 000              | 155 000                 |

Let's take a look at the brief process of developing a game on Unity. Development is underway on the Unity game engine version 2019.4.21f1 using the Perception Neuron Unity Integration 0.2.19 SDK. The SDK can be downloaded for free on the AxisNeuron website. The Perception Neuron motion pickup system shall be connected to the official Axis Neuron software to transmit the suit position data. Axis Neuron receives and processes motion data, which can then be exported to third-party software, in our case it is the Unity development environment. Consider the algorithm in more detail:

1) Create a scene. To create a scene, go to Unity Hub and click the New button to create a new project. In the opened window, select the 3D project and write the name of the project (Figure 1). After you create the project, an empty scene opens to which you want to import the SDK. SDK (from the English software development kit) - a development package containing scripts, models and much more. To import a package, click on the Assets and go to Importn Package > Custom Package and select the desired SDK (Figure 2).

![Figure 1. Creating a Project in Unity.](image)

After the successful import, let's go to the data transfer settings from Axis Neuron. In Axis Neuron, go to File > Settings > Broadcasting, select TCP protocol, and enable BVH data streaming (Figure 3). After applying these settings, Axis Neuron will be able to transfer suit position data to the Unity development environment. This completes the configuration of the work environment.

2) Setting up a character to create a character 3D a humanoid-type model and having a bone structure.

We will use the model from the Perception Neuron development package. Next, you add the Neuron Animator component Instance.cs and apply the settings shown in Figure 4. For our model to interact with other objects, you must add a Collider component for each individual body part. However, do this manually for quite some time, so we will use the tool from the Perception Neuron development kit.
Let’s go to the Neuron > SkeletonTolls masonry. This tool allows you to customize models that have a Neuron Animator component Instance.cs. To add a Collider component, press the AddColliders button (Figure 5). Thanks to this setting, each part of the body now has a Collider component (Figure 6).
4. Conclusion
Today, Perception Neuron is indeed the most affordable and easy-to-master product for recording a movement algorithm. In fact, Perception Neuron's capabilities are limited only by the fantasy of users. In the future of development, Perception Neuron can find its niche in medicine - accurate positioning of hands can help train surgeons. Theoretically, it is possible to use the device as a creative tool. In addition, device sensors can help track the algorithm and motility of human movement in certain conditions. What is not the field for conducting scientific research? As part of our research, work is carried out on real projects for any sphere, using the capabilities of a suit with wearable sensors when creating an application. It's incredibly interesting!

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