Methodology of Augmented Reality Application Development for Educational Purposes

Olga A. Medvedeva, Alina M. Galeeva, Chulpan B. Minnegalieva, Liliya E. Khairullina and Almaz F. Gilemzyanov

Kazan Federal University, 18 Kremlyovskaya str., Kazan, 420008, Russian Federation

Abstract
The article describes the use of augmented reality technologies in the modern educational process to increase educational motivation, multimedia and interactivity of the lecture material. The main purpose of the application: educational and cognitive. In the process of performing work, computer graphics, algorithms and modeling methods were used. Use case: there are special images on the stand that the mobile application recognizes and shows the created 3D models of the “Sun” and “Milky Way”. In addition, while the 3D model is being displayed, a short training audio lecture will be held. To create a 3D model of objects, the Unity program was used in conjunction with the augmented reality platform Vuforia.

Keywords
Augmented reality, Unity3D, Vuforia platform, mobile application, Education, Education Technology.

1. Introduction

Augmented reality is an interactive experience of a real-world environment where the objects that settle in the real world are upgraded by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory and olfactory. AR can be determined as a system that fulfills three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects [1]. The overlaid sensory information can be constructive (i.e. additive to the natural environment), or destructive (i.e. masking of the natural environment). This experience is seamlessly connected with the physical world such that it is believed as an immersive aspect of the real environment. Thus, augmented reality alters one's ongoing perception of a real-world environment, whereas virtual reality completely replaces the user's real-world environment with a simulated one. Augmented reality is related to two largely synonymous terms: mixed reality and computer-mediated reality [2].

In enhancing natural environments or situations and offering perceptually enriched experiences are realized by augmented reality. By means of advanced AR technologies (e.g. adding computer vision, incorporating AR cameras into smartphone applications and object recognition) the information about the surrounding real world of the user becomes interactive and digitally manipulated. Information about the environment and its objects is spread on the real world. This information can be virtual or real, e.g. seeing other real sensed or measured information such as electromagnetic radio waves overlaid in exact alignment with where they actually are in space. Augmented reality also has a lot of potential in the gathering and sharing of implicit knowledge [3]. Augmentation techniques are mostly fulfilled in real time and in semantic contexts with environmental elements. Immersive perceptual information is sometimes complied with supplemental information like scores over a live video feed of a sporting event. This combines the benefits of both augmented reality technology and heads up

DTTL-2021: International Workshop on Digital Technologies for Teaching and Learning, March 22-28, 2021, Kazan, Russia
EMAIL: OAMedvedeva@kpfu.ru (O.A. Medvedeva); galeeva.alm@gmail.com (A.M. Galeeva); mchulpan@gmail.com (Ch.B. Minnegalieva); lxayrullina@gmail.com (L.E. Khairullina); almazgilemzyanov@yandex.ru (A.F. Gilemzyanov)
ORCID: 0000-0002-1149-2106 (O.A. Medvedeva); 0000-0001-9687-0913 (A.M. Galeeva); 0000-0003-4648-1623 (Ch.B. Minnegalieva); 0000-0003-2178-2948 (L.E. Khairullina); 0000-0002-1691-9738 (A.F. Gilemzyanov)

display technology. The main value of augmented reality is the manner in which components of the digital world blend into a person's perception of the real world, not as a simple display of data, but through the integration of immersive sensations, which are perceived as natural parts of an environment.

In the work to create a 3D model of objects, the Unity program was used together with the Vuforia platform of augmented reality. Vuforia is an augmented reality software development kit (SDK) for mobile devices that enables the creation of augmented reality applications. It uses computer vision technology to recognize and track planar images and 3D objects in real time. This image registration capability enables developers to position and orient virtual objects, such as 3D models and other media, in relation to real world objects when they are viewed through the camera of a mobile device. The virtual object then tracks the position and orientation of the image in real-time so that the viewer's perspective on the object corresponds with the perspective on the target. It thus appears that the virtual object is a part of the real-world scene. The Vuforia SDK supports a variety of 2D and 3D target types including ‘markerless’ Image Targets, 3D Model Target, and a form of addressable Fiducial Marker, known as a VuMark. Additional features of the SDK include 6 degrees of freedom device localization in space, localized Occlusion Detection using ‘Virtual Buttons’, runtime image target selection, and the ability to create and reconfigure target sets programmatically at runtime. Vuforia provides Application Programming Interfaces (API) in C++, Java, Objective-C++ and the .NET languages through an extension to the Unity game engine. In this way, the SDK supports both native development for iOS, Android and UWP while it also enables the development of AR applications in Unity that are easily portable to both platforms [4].

2. Technologies and methods of development

Building augmented reality consists of two main principles: based on the marker and based on the coordinates of the user's location. Markerless technologies are often used in mobile devices, and are built by means of special sensors: accelerometer, gyroscope, magnetometer, GPS-receiver. But such an approach will not be examined in our article. We will consider on building augmented reality with the help of markers and computer vision algorithms. A marker is understood as an object located in the surrounding space, which is located and analyzed by special software for the subsequent rendering of virtual objects. According to the information about the position of the marker in space, the program can accurately project a virtual object onto it, from which the effect of its physical presence in the surrounding space will be achieved. Using additional graphic filters and high-quality models, a virtual object can become practically real and it will be difficult to differentiate it from other elements of the interior or exterior. A marker often looks like a piece of paper with some special image. The type of template can alter noticeably and depends on image recognition algorithms. Primarily, many markers are quite wide: they can be simple geometric shapes (for example, a circle, a square) and objects in the shape of a rectangle parallelepiped, and even people’s eyes and faces.

The theory of computer vision is fundamental for the development of augmented reality technologies, and especially in the field of the use of markers. The main direction of this discipline is the analysis and processing of images (including video stream). Computer vision algorithms allow to highlight basic features in the image (angles, area boundaries), search for shapes and objects in real time, perform 3D reconstruction of several photographs and much more.

In the area of augmented reality, computer vision algorithms are used to search for special markers in the video stream. Depending on the aim, both specially formed images and people's faces can act as a marker. After detecting the marker in the video stream and calculating its location, it is possible to build a matrix of projection and positioning of virtual models. Using them, you can overlay a virtual object on the video stream in such a way that the effect of presence is achieved. The main difficulty is exactly in finding the marker, detecting its location in the frame and projecting the virtual model appropriately. During the past decade, a large theoretical base has been created in the field of image processing and searching for various objects on it. First of all, it concerns the methods of contour analysis, template matching, feature detection and genetic algorithms. From the point of view of building augmented reality, the last two approaches are frequently used. Let us give small explanations for each of them.

Genetic algorithms are heuristic search algorithms used to solve the problems of optimization and modeling by randomly selecting, combining, and varying the desired parameters using mechanisms resembling to biological evolution. In computer vision they are used to search for an object of a given class in a static image or video stream. In the first place, it is necessary to train the algorithm by using two different sets of images: 1. with contain the necessary object; 2. false images without the desired object. At the same time, a great number of images are used for training, and the more there are, the better the algorithm will work. Different key properties are highlighted for each image: borders, lines, and central elements. A statistical model is built based on them, which is then used to search for an object in the image. An example of using this approach is the algorithm for recognizing faces and eyes in the video stream. Gradually training the algorithm, you can achieve high results in finding a given class of objects. However, the need for training just makes the use of genetic algorithms quite problematic. For their good work, a significant number of different images are required, and building a classifier for each object can take a long time [5].

The concept of feature detection in computer vision refers to methods that aim to calculate the abstractions of an image and highlight key features on it. These features can be either isolated points, curves, or connected areas. There is no strict definition of what a key feature of an image is. Each algorithm understands its own meaning (angles, faces, areas, etc.). Algorithms are often used to search for markers that search and compare images by key points. A key point is a certain part of the image that is distinctive for a given image. What exactly is taken for this point depends on the algorithm used.

Three components are used to detect them and then compare them:

• Detector - searches for key points in the image.

• Descriptor - creates a description of the found key points, evaluating their positions through the description of the surrounding areas.

• Matcher - builds matches between two sets of points.

First, the detector is used to search for key points of the template image. The resulting points are then described using a descriptor. This information is saved in a separate file (or database) so that this process is not repeated. When processing a video stream to search for a given template, the described process is performed for each frame (except for saving data) [6]. A matcher is used to match key points and descriptors. It is natural to assume that different algorithms work with different speed and efficiency. When using them to build augmented reality, it is necessary to use only those that show high speed with a fairly good quality of tracking the positions of key points. Otherwise, we may get noticeable delays in the captured video data. To increase the speed of the feature points detection algorithms, various methods of filtering points are used to minimize their number and filter out completely bad combinations. This way, you can not only improve the speed of algorithms, but also the quality of tracking markers.

3. Experiment

This article describes the development of augmented reality applications. The main purpose of the application: educational and cognitive. Theme of the application: space. Use case: on the stand there are special images that the application will recognize and show the created 3D model. Also, while the 3D model is being displayed, a short training lecture will be played. Images that the application recognizes are presented in Figure 1 and Figure 2.

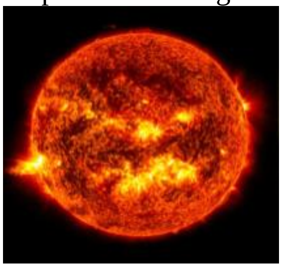

Figure 1: Image of the Sun

Figure 2. Image of the Galaxy

To create a 3D model of objects, the Unity program was used in conjunction with the augmented reality platform Vuforia.

The following objects were used to create the “Sun” model:

- PSunSurface – is responsible for ensuring that all other objects are collected together.
- PSCorona – simulates the crown of the Sun.
- PSLoop – models light rings (radiation) around the Sun.
- SunSphere – responsible for the model of the sphere of the Sun.
- ImageTarget – responsible for a special image.
- ARCamera – is responsible for visualizing the device’s camera.
- PSLoop, PSCorona – created using the Particle System effect.

Configure PSCorona (Figure 3.):

- Duration – effect duration.
- Looping – repeat Effect.
- Prewarm – the effect starts playing immediately upon hovering over the picture.
- Emission – the number of particles formed in 1 second.

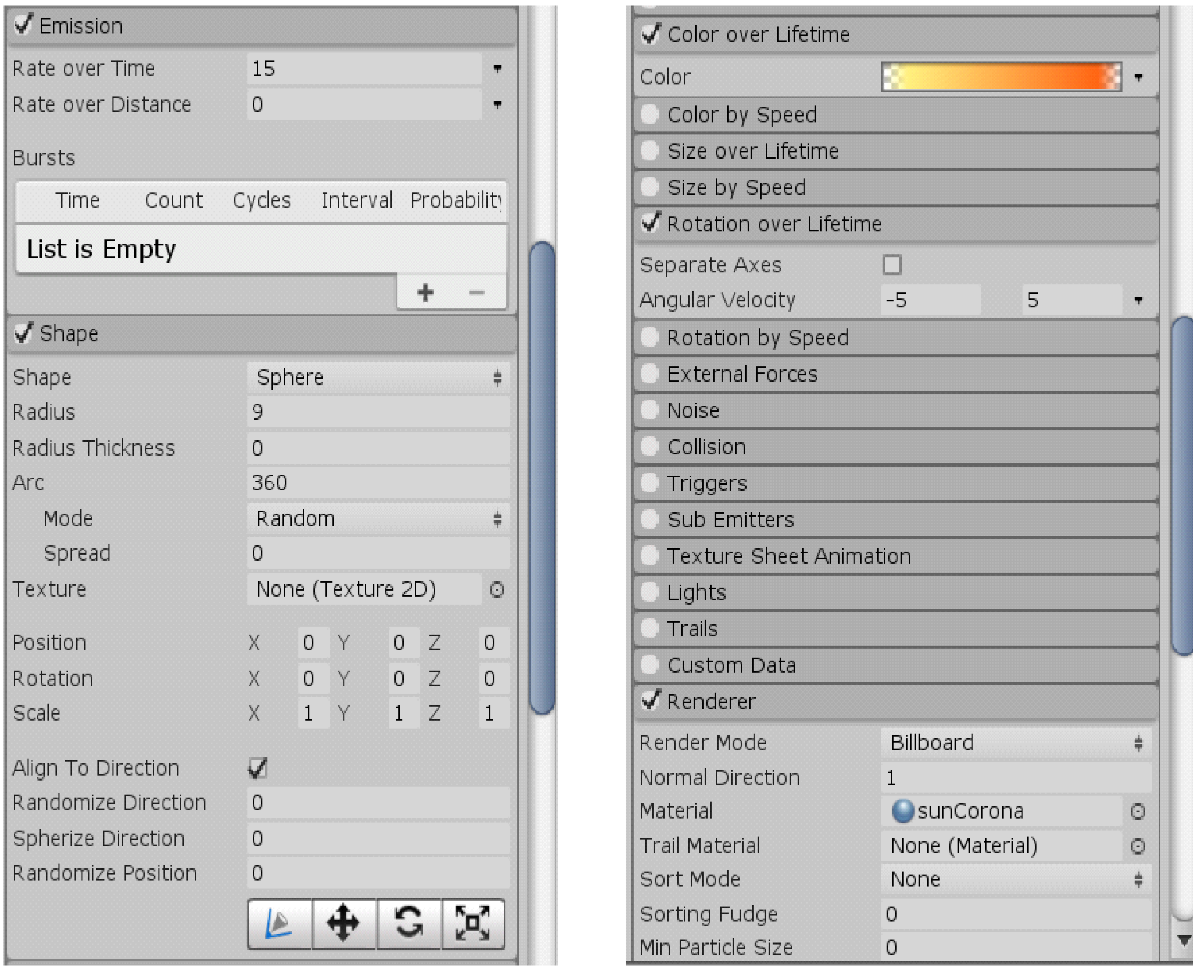

Figure 3: Configure PSCorona.

The material used to create the crown is shown in Figure 4. To create it you need to find a suitable image of smoky rings. You should import it into the project, then select Shader Particles/Standard Unlit. After that you need to create the material in the project, insert the selected image into the oAlbedo parameter. In the same place you should select the orange color.

Figure 4: The material used to create the crown.

Figure 5 shows Configure PSLoop. The material used to create the rings around the Sun is shown in Figure 6. To create it, it is necessary need to find a suitable picture of the luminous ring, to import it into the project and select Shader Particles / Standard Unlit. Figure 7 shows Configure SunSphere.

First, you need to find the desired image and then go to the site https://developer.vuforia.com/. It is necessary to register and create a database. You need to load the selected picture into it. It is desirable that the image score is at least 3 points for the correct image recognition by the camera of the device. Then you need to download the database and import it into the project. After that, in the ImageTarget settings you should select the database and the image itself from it in the settings.

Next, you need to download the audio, which you will play over the image and import it into the project. After that, you should check the box next to Audio Source. In the AudioClip item you should insert the imported audio. In order for the audio to play, you need to change the original script. Then you should go to Packages/Vuforia Engine AR/Scripts/, select the file DefaultTrackableEventHandler.cs, in which you need find the OnTrackableStateChanged method. It is necessary to add the lines au-dio.Play() and audio.Stop () to the appropriate places (Figure 8.).

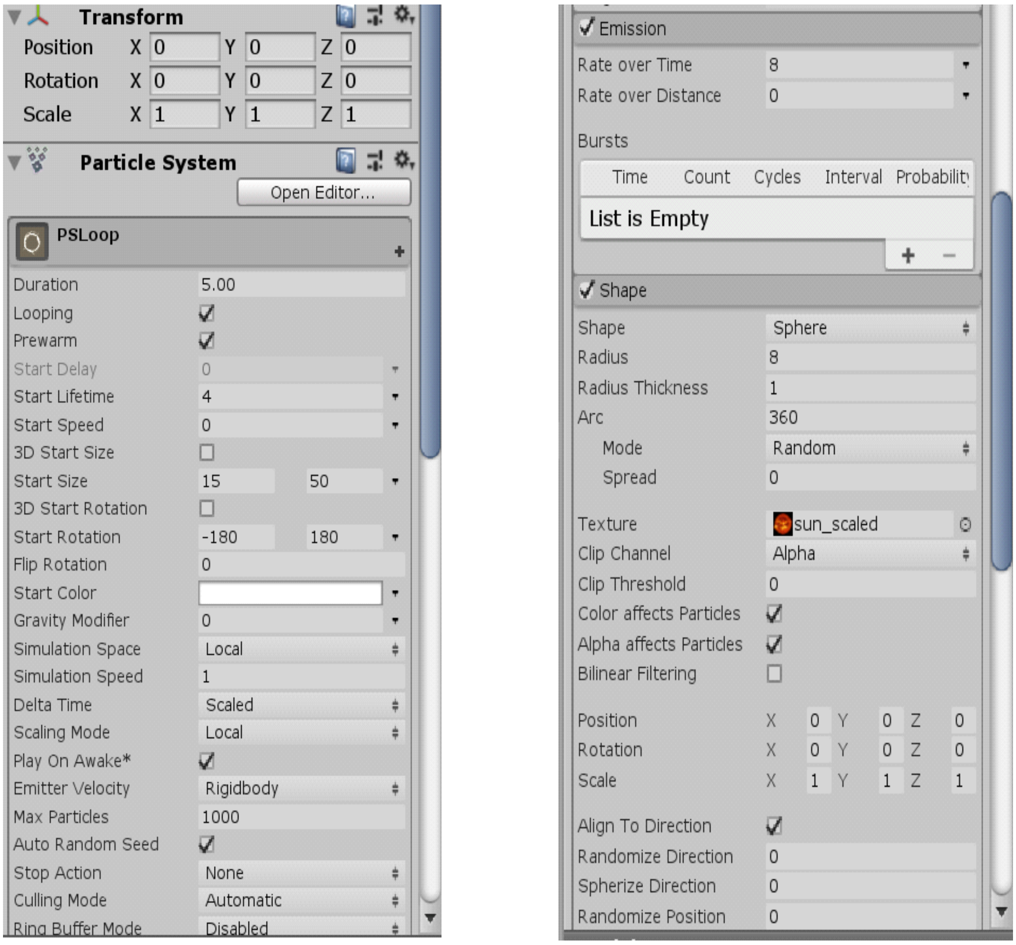

Figure 5: Configure PSLoop.

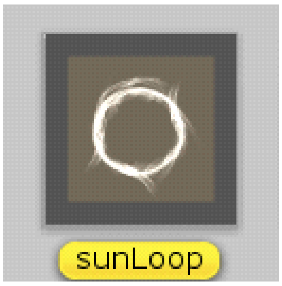

Figure 6: The material used to create the rings around the Sun.

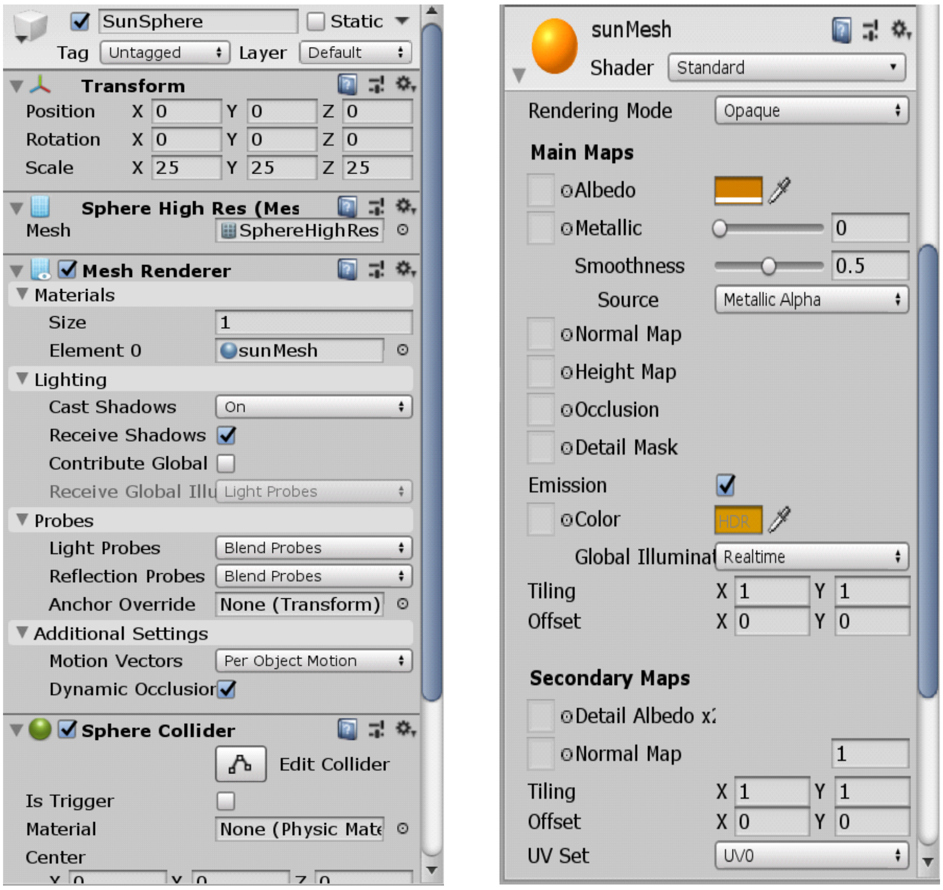

Figure 7: Configure SunSphere.

After that, you should add ARCamera to the project structure and set it as if the device's camera was positioned relative to the visible ImageTarget. Next, you need to go to the License Manager, select the created database and copy License Key. Then it is required to find the VuforiaConfiguration file in the Resources folder and insert the License Key in the App License Key section.

Finally, you are supposed to put the project together. The final Sun model is shown in Figure 9.

To create a model of "Milky Way", the following items were used:

- Galaxy – responsible for ensuring that certain objects are brought together.
- Stars – simulates stars in a galaxy.
- glowCentre – simulates the center of the galaxy.
- mist – responsible for creating the fog effect.
- ImageTarget – responsible for a special image.
- ARCamera – is responsible for visualizing the device's camera.
- Stars, glowCentre, mist – created using the Particle System effect.

The material that was used to create the stars is shown in Figure 10. To create it in Photoshop, put a large white dot with a brush with blur along the edges of the canvas. You need create the material in the project, insert the selected image into the oAlbedo parameter. The material that was used to create the fog is shown in Figure 11. To create it, you need to find a picture of smoke, to import it into the project and select Shader Particles/Standard Unlit. You need create the material in the project, insert the selected image into the oAlbedo parameter.

```
public void OnTrackableStateChanged(
    TrackableBehaviour.Status previousStatus,
    TrackableBehaviour.Status newStatus)
{
    m_PreviousStatus = previousStatus;
    m_NewStatus = newStatus;

    Debug.Log("Trackable " + mTrackableBehaviour.TrackableName +
              " " + mTrackableBehaviour.CurrentStatus +
              " -- " + mTrackableBehaviour.CurrentStatusInfo);

    if (newStatus == TrackableBehaviour.Status.DETECTED ||
        newStatus == TrackableBehaviour.Status.TRACKED ||
        newStatus == TrackableBehaviour.Status.EXTENDED_TRACKED)
    {
        audio.Play();
        OnTrackingFound();
    }
    else if (previousStatus == TrackableBehaviour.Status.TRACKED &&
             newStatus == TrackableBehaviour.Status.NO_POSE)

    {
        audio.Stop();
        OnTrackingLost();
    }
    else
    {
        // For combo of previousStatus=UNKNOWN + newStatus=UNKNOWN|NOT_FOUND
        // Vuforia is starting, but tracking has not been lost or found yet
        // Call OnTrackingLost() to hide the augmentations

        audio.Stop();
        OnTrackingLost();
    }
}
```

Figure 8: Method for playing audio.

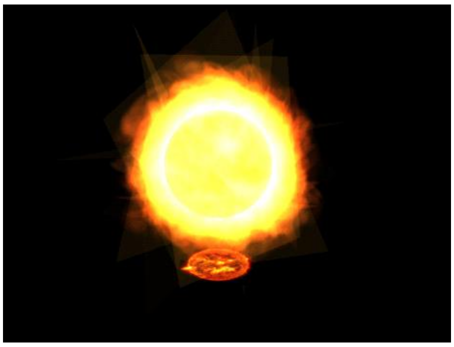

Figure 9: The final Sun model.

Figure 10: The material that was used to create the stars.

Figure 11: The material that was used to create the fog.

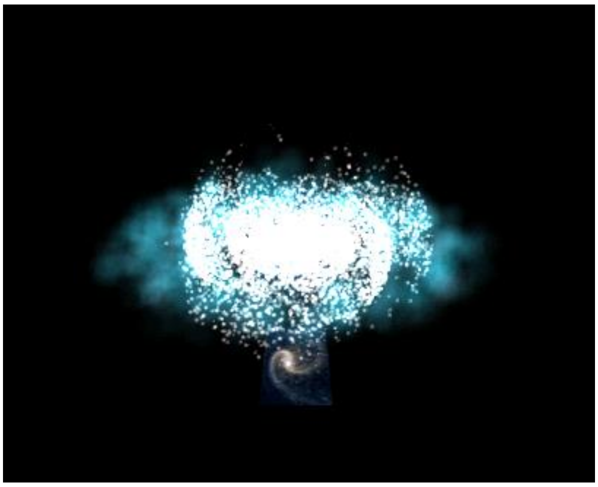

Figure 12: The final «Milky Way» model.

4. Conclusion

Practicing the possibility of augmented reality in education can restore the process for the visual perception of the necessary information. The article based on examples of using augmented reality technology. The possibility of using this technology in the educational environment for the visual modeling of educational material, supplementing it with visual information, while developing spatial representations, imagination, volumetric design skills, which saves teachers and students time on the transfer and assimilation of educational information, and accelerates the learning process. The application can be downloaded from the link:

https://drive.google.com/open?id=1JjjA2SHPsXBDNtOFEwbFCfVChe7hsdkK.

Augmented reality technology can be applied in a large number of solutions for the educational process, for example: replacing real experiments with virtual ones in case it is not possible to work with equipment or part of it; adding three-dimensional objects to interactive teaching aids; presenting interactive information on whiteboards in classrooms without having to replace them with expensive ones; introducing interactive assistants to the educational process; learning foreign languages by replacing the words being studied with virtual objects, etc.

5. References

[1] A.M. Galeeva, Development of an augmented reality mobile application in educational purposes, A.M. Galeeva, S.I. Mustafina, O.A. Medvedeva, VI International Conference and Youth School INFORMATION TECHNOLOGIES AND NANOTECHNOLOGIES (ITNT-2020), (May 26–29, 2020), Samara, 2020, pp. 1030–1038.

[2] R.A. Grigorev, B.A. Valijanov, O.A. Medvedeva, S.A. Mustafina, Information system development using augmented reality tools, CEUR Workshop Proceedings 2525 (2019). URL: http://ceur-ws.org/Vol-2525/ITTCS-19_paper_16.pdf

[3] D. Kurz, S. Benhimane, Gravity-aware handheld augmented reality, Mixed and Augmented Reality (ISMAR), 2011, 10th IEEE International Symposium on IEEE, 2011, pp. 111–120.

[4] K. Lee, Augmented reality in education and training, TechTrends 56 (2), (2012), pp. 13–21.

[5] O. Medvedeva, S. Mustafina, Using of Interval Analysis Algorithms for Technical Systems Optimization Problem Solving, Proceedings of 2018 IEEE East-West Design and Test Symposium, EWDTS, 2018, Art. No 8524746.

[6] O. Medvedeva, S. Mustafina, D. Petrov, Getting the Emotional Coloring of Videos for Further Teaching of Neural Networks, Proceedings of 2018 IEEE East-West Design and Test Symposium, EWDTS, 2018, Art. No 8524856.

[7] W. Pasman, Augmented reality with large 3D models on a PDA: implementation, performance and use experiences, Proceedings of the 2004 ACM SIGGRAPH international conference on Virtual Reality continuum and its applications in industry, 2004, pp. 344–351.
[8] W. Pasman, C. Woodward, Implementation of an Augmented Reality System on a PDA, Proceedings of the 2nd IEEE/ACM International Symposium on Mixed and Augmented Reality, IEEE Computer Society (2003) 276–289.