

# Using the Unity 3D Environment and the Vuforia Plugin to Develop an AR Application

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**Abstract.** Currently, more and more interactive media environments are offered to users. Augmented reality (AR) technologies are one of the environments where interactive interaction is provided and which can integrate objects in virtual environments with real objects. Augmented reality technologies are used in many areas, including in the field of education. Some aspects of the development of augmented reality applications are discussed in the article. It was revealed that the Unity platform and the Vuforia plugin are used as the most popular tools by AR application developers, which have a number of advantages. The process of developing an AR application for the education sector using the Unity environment, the C# programming language and Vuforia is considered. The Unity 3D environment and the Vuforia plugin are in practice an effective combination of flexible mobile application development tools with augmented reality elements.

**Keywords:** virtual environment, interactive interaction, augmented reality technology, Augmented reality, AR, AR application, Unity 3D, Vuforia, AR application development algorithm, AR visualization model.

**Introduction.** Human-computer interaction is a dynamically developing area of science. Continuous improvement in technology leads to the possibility of using new forms of user interface.

The globalization of virtual reality has led to the introduction of the term «augmented reality» into scientific circulation. While modern user interface technologies are mainly focused on human-computer interaction, computer-assisted augmented reality offers an improvement on the human interface and the real world. Augmented Reality (AR) is a technology that adds digital objects to the real, physical world, increases engagement and interaction, and provides a richer human user experience [1].

Augmented reality technologies are used in applications used in various areas of life: medicine, education, tourism, art, trade, history, geography, etc.

For example, the BBC Civilizations AR app is often cited as setting the benchmark for future AR apps (<https://www.bbc.co.uk/taster/pilots/civilisations-ar>), the SketchAR app is for creative AR tracing needs (<https://sketchar.tech/>), «Find Your Car with AR» app for targeted search of a parked car (<https://apps.apple.com/us/app/find-your-car-with-ar/id370836023>) and etc. Thus, the market for AR applications is actively developing in various directions, which confirms the

relevance of the study.

**Research methods.** Augmented reality technologies add some interactive layers or elements of three-dimensional space to the real world. Unlike augmented reality, virtual reality (VR) is a complete immersion in the created virtual digital world. Various hardware products are used to experience virtual and augmented reality, such as 3D cameras, glasses, displays, helmets, head-mounted displays (HUDs), sensors, smartphones, etc. [2].

Ronald Azuma identified a number of features that augmented reality should have: a combination of the real and virtual worlds, interactivity, and a three-dimensional representation of objects [3].

Directions for solving problems related to image processing in augmented reality are considered in the work of Chimienti, Iliano, Dassisti, Dini (2010) [4]; issues of developing a clear and understandable interface in AR applications, ways to reduce human errors when using AR are proposed by Martinetti A. et al. (2017) [5].

The issues of using VR and AR technologies in education are discussed in [6], in the tourism field – Beck, J. Rainoldi, M. and Egger, R. (2019) [7], the benefits of using AR applications in education are described in [8].

Currently, in the field of AR, there are a number of platforms and software solutions that support application development technologies and tools. In [9, 10], a comparative analysis of the AR SDK (Augmented Reality Software Development Kit) toolset was carried out, according to which Vuforia, Wikitude, EasyAR are the most convenient. To develop AR applications, we will use AR Vuforia on the Unity 3D platform, the combination of which allows you to create applications for popular platforms Windows, Android, MacOS, Apple iOS. There are a number of other advantages: the ability to create 2D and 3D applications, the use of JavaScript, C #, the presence of the Asset Store, working with resources via Drag-and-Drop and, importantly, the availability of a free version with some limitations. The Vuforia engine is easy to add to any project and supports AR app development for Android, iOS, Lumin and UWP devices. The Vuforia engine package can be added to a Unity project from a Git URL (Figure 1).

**Discussion of the results.** As an example, consider the procedure for developing an augmented reality application «Virtual Astronomy» for secondary education using the Unity development environment and the Vuforia plugin.

When planning an AR application, the steps that are typical for the development of any software are performed, namely, analysis of requirements, determination of the purpose and objectives of the application, determination of functional features.

The purpose of the software product is to provide 3D visualization of celestial objects and interactive study of educational material on school astronomy. Application tasks: organization of personalized access to the application and provision of information with augmented reality by sections of the material.

Key functional requirements: registration for access to the application; provision of educational material with test questions in sections; activation of the AR mode through the integration of the mobile

device's camera API; capturing an image from the camera of a mobile device; recognition of a marker (object binding image) on the image from the camera stream of the mobile device; loading and activation of an AR object using Vuforia in the active camera mode of a mobile device; dynamic display (animation) of an AR object using Vuforia in the active camera mode of a mobile device.

At the design stage, a number of UML diagrams are built that describe the functionality of the application. A use case diagram is shown in Figure 2.

The application class diagram is shown in Figure 3. The main classes that implement the business logic of the application are: AR, DeviceAPI, Main, Registration, Autorize, UserDataHandler, Theory, Testing, CourseTopics, Content, Questions, as well as two interfaces for accessing the Vuforia and Unity logic.

The application deployment diagram is shown in Figure 4. To deploy the application, a development computer is used, which includes the Unity 3D environment, Vuforia API dependencies, .NET Framework 4.7, Visual Studio environment, as well as the Android target support module and a mobile device or emulator (virtual machine) with installed Android operating system.

During the development of an AR application, after installing the Unity environment and the Vuforia Engine plugin in your project, you must also add the Unity ARCamera object, which includes VuforiaBehaviour to add support for augmented reality applications for both handheld devices and digital glasses. For the app to work properly, you need to remove the default Main Camera object and replace it with the AR Camera object that comes with the Vuforia Engine.

Then the main Vuforia AR scenes are configured: go to the Vuforia Engine Menu, select an Image Target or other targets to use (VuMark, Ground Plane, Mid). Each Vuforia engine object can be configured in

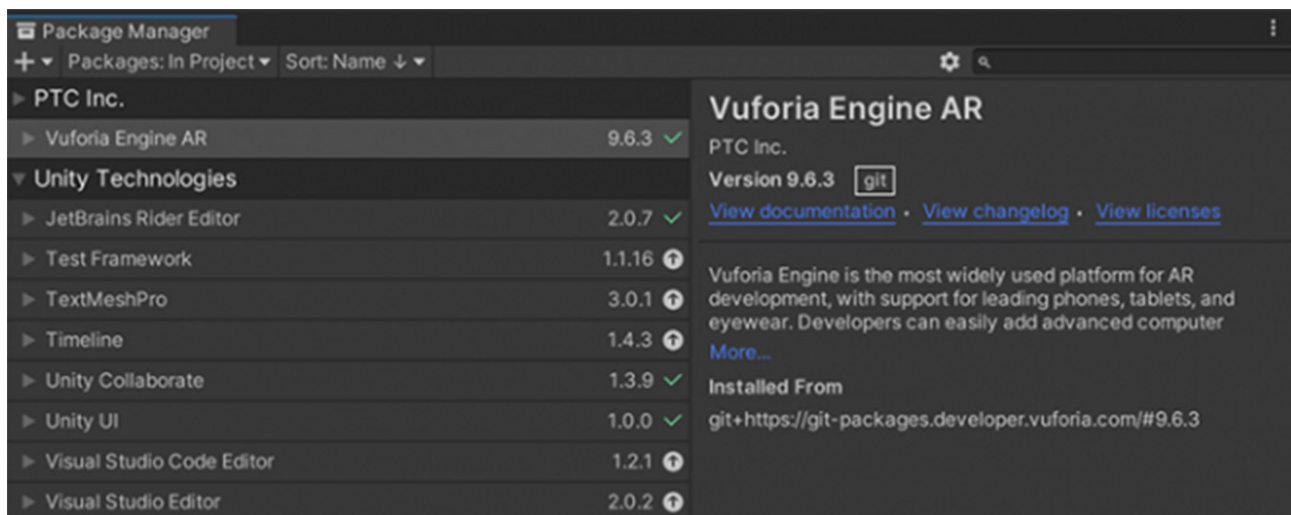


Figure 1 – Adding the Vuforia Engine AR

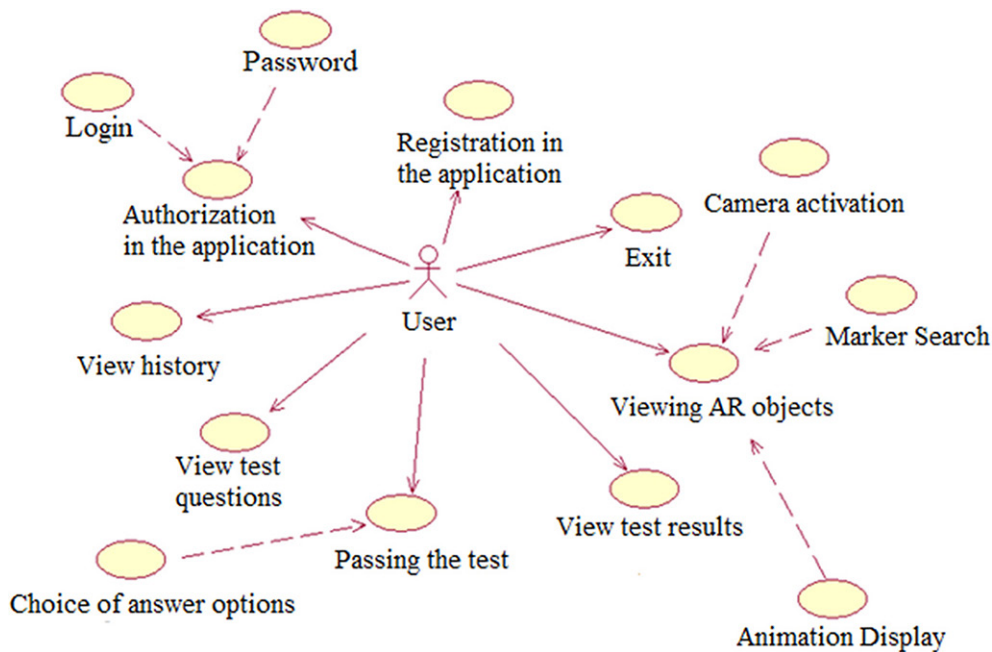


Figure 2 – Use Case Diagram

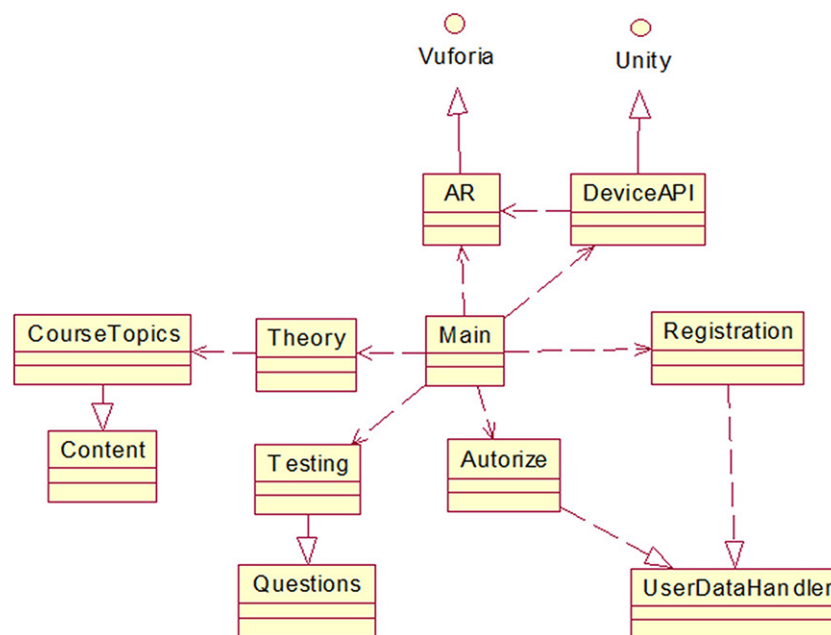


Figure 3 – App Class Diagram

the GameObject Inspector. Accurate scale between Vuforia targets and physical prints or objects must be maintained precisely, or image quality is lost. Digital content is then added to the target, it can be a simple cube from a GameObject – 3D Object – Cube, or content from the Unity Asset Store or developer master samples.

In the code for displaying AR objects, the following actions have been worked out: setting up the transmission of information from the camera; setting the tracking of the desired image; transfer of virtual data to the required object. A number of key

methods are described:

1. ARScreen.cs is a C# code file that implements the functionality of loading augmented reality mode and switching between it and the main application workflow (void Start() and private void OpenHome() methods).

2. RegistraionScreen.cs, LoginScreen.cs, MenuScreen.cs, PracticeAstronomyScreen.cs are C# code files that contain methods for registering, logging, navigating through the forms of an authorized user application, and testing.

3. ScreenManager.cs is a C# code file that

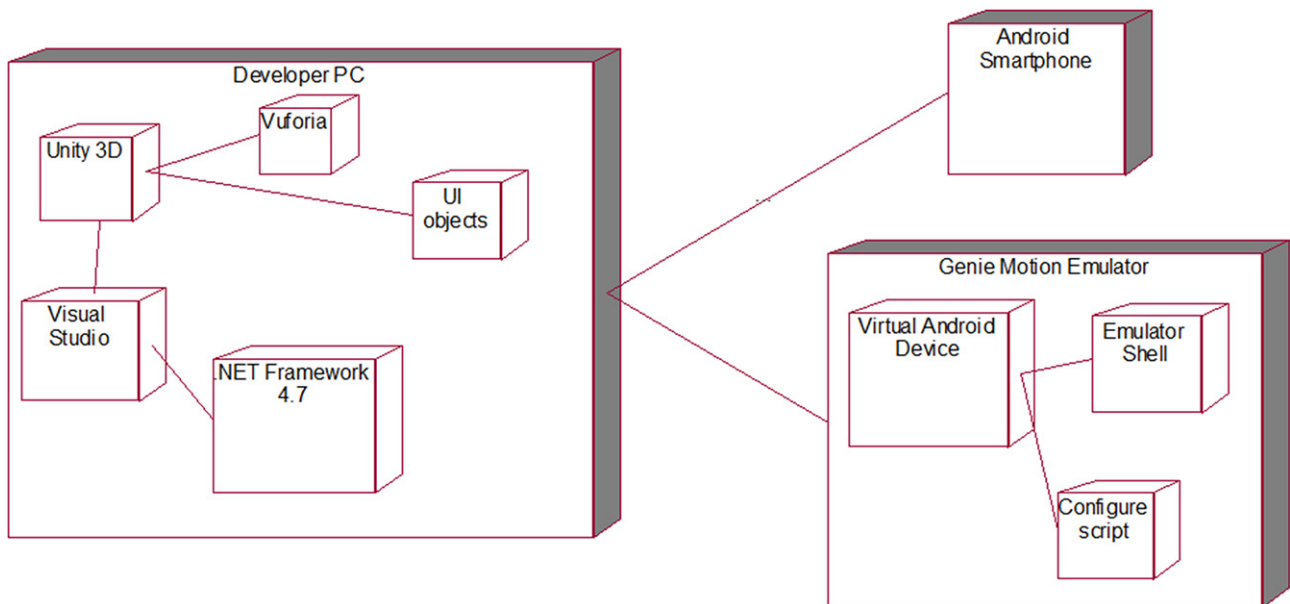


Figure 4 – Application Deployment Diagram

implements the interaction between user activities and the Vuforia API loading mode by using the public static void TransitScreen() method, which also allows you to transfer control of the device's camera and synchronize it with the search flow for markers in the image.

4. AddVuforiaEnginePackage.cs is a C# file that implements and defines the order in which Vuforia elements and functionality are included in applications, in particular:

- IsUsingUrl(Manifest manifest) – support for loading the necessary dependencies through a remote repository using the application manifest;
- void DisplayAddPackageDialogue(Manifest manifest) – displaying dialog boxes when working with the API according to the application manifest;
- void UpdateManifest(Manifest manifest) – update the application manifest when changing the display order of objects or other settings;
- void SetVuforiaVersion(Manifest manifest) – determines the version of the active instance of the Vuforia object in AR mode;
- void JsonSerialize(string path) – serialization of model and object data into json format;
- GetJsonString() – reading data of models and objects from json into strings;
- Manifest JsonDeserialize(string path) – deserialization of model and object data from json format;
- int GetDependenciesStart(string json) – get instances of active dependencies when AR mode starts;
- int GetDependenciesEnd(string jsonString, int dependenciesStartIndex) – get dependency instances when exiting AR mode to gracefully close image capture mode.

The configuration form of the interactive AR

visualization model in the Unity environment using Vuforia in the application project is shown in Figure 5.

The buttons for switching to the main form and activating the augmented reality mode are located in the upper left and right corners, respectively. After clicking, the form for capturing an image from the smartphone camera via the Vuforia API is activated. When the device camera focuses on the image with the specified markers, the animation is loaded and rendered in augmented reality mode. An object is displayed within the space of this form, with the ability to scale. After loading all the objects and zooming the image in the capture mode, the animation of the planets of the solar system is displayed. The result of displaying a set of objects when capturing a marker on an image from a smartphone camera is shown in Figure 6.

When changing the image capture angle, objects can move proportionally to it. After returning to the main form and switching to the testing activity, the corresponding form is displayed, which contains a button to return to the main activity.

**Conclusion.** Based on the analysis of the development of augmented reality applications for various application areas, we can conclude that the Unity platform, which implements a large number of libraries, dependencies and artifacts, actually dominates the market.

As an example, an AR application was developed using the Unity 3D environment, the C# programming language and Vuforia. The application allows you to increase the efficiency of visualization of astronomy objects in augmented reality mode by capturing markers with a smartphone camera, which is especially important for secondary school.

It was revealed that the Unity 3D environ-



ment and the Vuforia plug-in are in practice an effective combination of flexible mobile application development tools with augmented reality elements, having the potential to expand the application functionality to full-fledged virtual reality (by

connecting additional hardware, in particular virtual helmets) due to integration mechanisms with each other. This may become the next topical direction for the development of this project in the future.

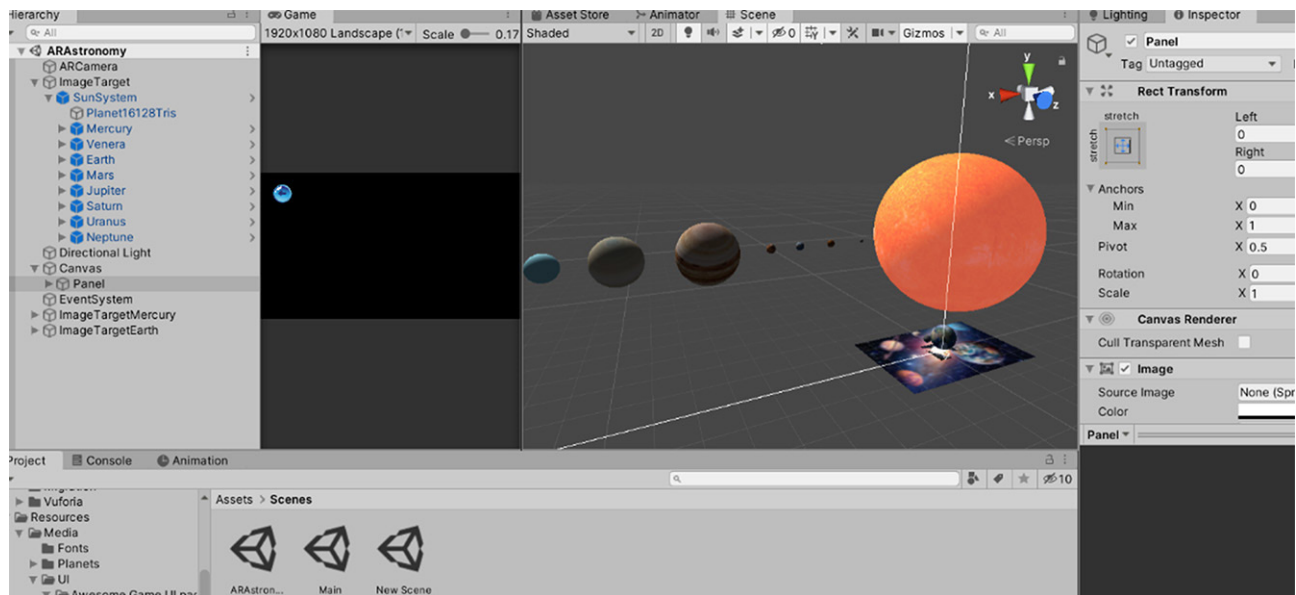


Figure 5 – Configuration of an AR visualization model

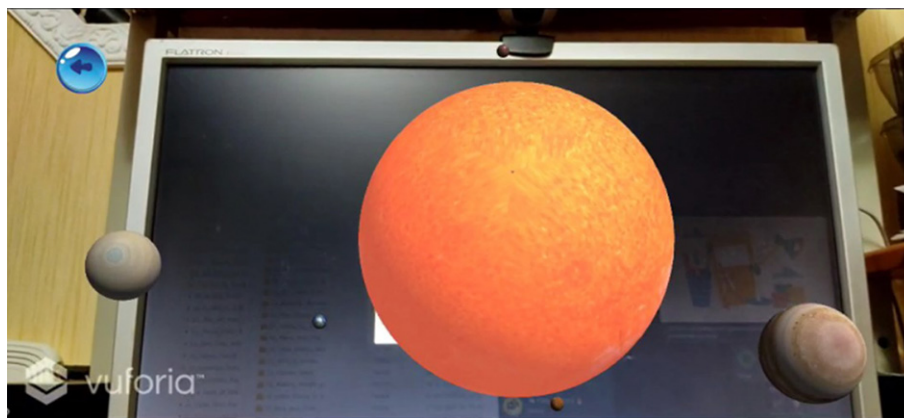


Figure 6 – The result of displaying a set of objects when capturing a marker on an image from a smartphone camera

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#### **AR қосымшасын жасау үшін Unity 3D ортасын және Vuforia плагинін қолдану**

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**Аңдатпа.** Қазіргі уақытта пайдаланушыларға көбірек интерактивті медиа орталар ұсынылады. Интерактивті өзара әрекеттесуді қамтамасыз ететін және виртуалды ортада объектілерді нақты объектілермен біріктіре алатын орталардың бірі – толықтырылған шындық (AR) технологиялары. Толықтырылған шындық технологиялары көптеген бағыттарда, соның ішінде білім беру саласында да қолданылады. Жұмыста толықтырылған шындық қосымшаларын жасаудың кейбір аспектілері қарастырылған. AR қосымшаларын әзірлеушілер үшін ең танымал құралдар Unity платформасы және бірқатар артықшылықтары бар Vuforia плагині екені анықталды. Unity ортасы, C# бағдарламалау тілі және Vuforia көмегімен білім беру секторы үшін AR қосымшасын әзірлеу процесі қарастырылған. Unity 3D ортасы және Vuforia плагині іс жүзінде кеңейтілген шындық элементтері бар мобильді қосымшаларды икемді әзірлеу құралдарының тиімді комбинациясы болып табылады.

**Кілт сөздер:** виртуалды орта, интерактивті өзара әрекеттесу, толықтырылған шындық технологиясы, Augmented reality AR, AR-қосымша, Unity 3D, Vuforia, AR-қосымшасын әзірлеу алгоритмі, визуализацияның AR-моделі.

#### **Применение среды Unity 3D и плагина Vuforia для разработки AR-приложения**

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**Аннотация.** В настоящее время все больше интерактивных медиасред предлагаются пользователям. Одной из сред, где обеспечивается интерактивное взаимодействие и которая может интегрировать объекты в виртуальных средах с реальными объектами, являются технологии дополненной реальности (AR). Технологии дополненной реальности применяются во многих направлениях, в том числе и в сфере образования. В работе рассмотрены некоторые аспекты разработки приложений дополненной реальности. Выявлено, что в качестве наиболее востребованных инструментов разработчиками AR-приложений применяются платформа Unity и плагин Vuforia, которые обладают рядом преимуществ. Рассмотрен процесс разработки AR-приложения для сферы образования с помощью среды Unity, языка программирования C# и Vuforia. Среда Unity 3D и плагин Vuforia на практике являются эффективной комбинацией средств гибкой разработки мобильных приложений с элементами дополненной реальности.

**Ключевые слова:** виртуальная среда, интерактивное взаимодействие, технология дополненной реальности, Augmented reality, AR, AR-приложение, Unity 3D, Vuforia, алгоритм разработки AR-приложения, AR модель визуализации.

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