Analysis of tools for the development of augmented reality technologies

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Abstract

The article considers cross-platform products that should be used to develop augmented reality technologies: Unreal Development, Kit, Unity, Godot, Engine, Cocos2D, MonoGame, Unreal Engine, Marmalade, and others. Also, the possibilities of known SDKs for the development of augmented reality applications (Wikitude, Vuforia, Kudan, Maxst, Xzimg, NyARToolkit, Metaio SDK) are given. It is established that for the development of augmented reality technologies can be used not only cross-platform engines but also sets of development tools. Such kits allow you to speed up and simplify the process of developing any program with elements of augmented reality. These advantages and disadvantages will help beginners to choose the most convenient tool for developing augmented reality technologies. In addition, the article attempts to identify criteria and indicators for the selection of such environments, as well as their expert evaluation.

Keywords

development tools, technologies, augmented reality, SDK

1. Introduction

Recently, scientists have been paying special attention to the use of augmented reality in various classes, both in general secondary education [1, 2] and in higher education [3, 4]. Therefore, the development of various augmented reality (AR) tools is also relevant. However, to develop any AR tool, it is need to make a choice of appropriate development tools.

In particular, Kiv et al. [5] explored the possibilities of transforming augmented reality into augmented education. Morkun et al. [6] considered augmented reality as a tool for visualization of ultrasound propagation in heterogeneous media based on the k-space method.

Chen et al. [7] conducted a review of augmented reality technology. In their article, they introduces the development tools, key technologies and application of AR in several field.

Some authors consider the possibility of developing augmented reality technologies. In particular, Kanivets et al. [8] investigated the development of mobile applications of augmented reality for projects with projection drawings, Bilous et al. [9] proposed the development of AR-applications as a promising area of research for students, and Hordiienko et al. [10] - the development of a model of the solar system in AR and 3D.

Others consider the possibility of using augmented reality technologies in education. Thus, Shyshkina and Marienko [11] studied augmented reality as a tool for open science platform by research collaboration in virtual teams; Iatsyshyn et al. [12] studied the possibilities of using the application of augmented reality technologies for the preparation of specialists of the new technological era; Midak et al. [13] considered augmented reality technology within studying natural subjects in primary school; Rashevska et al. [14] described the possibilities of using augmented reality tools in the teaching of two-dimensional plane geometry; Oleksiuk and Oleksiuk [15] investigated exploring the potential of augmented reality for teaching school computer science.

That is why the purpose of the article is to analyze the available tools to develop augmented reality technologies, in particular for the education sector.

2. Results

2.1. Overview of available tools for working with AR

At the moment, the choice of cross-platform products is small. Here are some of the most popular cross-platform engines on the market: Unreal Development Kit, Unity, Godot, Engine, Cocos2D, MonoGame, Marmalade, and others.

All these engines have good technical performance and support most mobile platforms. However, most developers make their choice based not only on the number of supported platforms but also on the ease of transferring code to different platforms, performance, and more.

Since you need a tool to create applications for phones with the Android operating system, several options have been selected.

Cocos2d is a framework for creating applications and games for iOS, Android, Windows Phone. The engine is completely free, there are many branches: Cocos2d-ObjC, Cocos2d-x, Cocos2d-html5, and Cocos2d-XNA. Most often Cocos2d is used to create games for iOS. The engine is highly adaptable, well suited for novice developers. In terms of performance, it beats Unity, but the design of the Cocos2d itself is worse than the competitor.

Unreal Engine 4 is a gaming engine created by Epic Games. Unreal Engine 4 is the most popular game engine for creating movies and AAA projects.

Godot Engine is free game engine, has a powerful visual scene editor, animation editor, its integrated development environment.

Unity is a gaming engine for developing 2D and 3D applications and games for various platforms [16, 17, 18]. Unity can be downloaded for free. This version will not be a demo version or for a while, you can use it to create your project. Only it is impossible to expose it paid in the market, it is necessary to put advertising in the application or game.

The Unity development environment is the most convenient for the software implementation of augmented reality technology. It is a high-level development environment for applications and games. Includes a powerful editor with a graphical interface and a graphical engine optimized for mobile devices.

Developer scripts can be written in any .NET programming language and compiled into regularly managed assemblies (DLLs). There are built-in compilers for C#, UnityScript, and Boo. At the same time, there is a possibility of the organization of the interface with the external code. The advantages also include an active community of developers and many ready-made developments and extensions.

Here are the main criteria by which to describe Unity as a modern gaming engine with rich potential and ample opportunities (see table 1) [19].

Table 1
The main characteristics of Unity

Indicator	Characteristic
Sound	Own audio plug-ins, the ability to use third-party audio plug-ins; call animation scripts – create keyframes in the animation editor and link scripts to them; sound mood changes, call animation scripts – create keyframes in the animation editor and link scripts to them; ability to change sound settings.
Graphics	A way of representing objects that do not have clear geometric boundaries (smoke, vapors, liquids, etc.); ability to place images from the camera not on the screen, but in the texture, needed to create some effects; built-in sprite editor can automatically cut a raster with sprites into frames and create animation from them. Link events to specific animation keyframes; use of various types of compression of textures and packing of the used frames of sprites in one resource; built-in Box2D library, and support for NVIDIA PhysX (physics implemented through use in GPU calculations); alphabet, cropping part of the image on the mask, which is placed in the alpha component of the texture; super-accurate collision detection; dynamic Batching, a rendering optimization algorithm allows you to increase productivity.
Animation	Visual state editor (State machines), which can be linked to game objects and use to create and improve animation; integrated animation editor; create scripts using c#, JavaScript, or Boo; native integration with Visual Studio; realistic animation; one-click placement; optimized graphics.

Here are the advantages and disadvantages of Unity:

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- advantages:
    - ease of use and performance;
    - a huge number of supported platforms: Windows, iOS, Android;
    - ability to run the project in the browser as an HTML5 application;
    - good performance both in small games on weak mobile platforms, and in difficult big projects on high-end consoles;
    - support for both 2D and 3D modes without much effort;
    - powerful built-in animation system Mechanim;

– C# or JavaScript programming language;
– large community, where you can get support and answers to questions of interest to Unity;
– built-in visual editor, greatly simplifies and speeds up the process of creating a program;
– assets store, a store for developers that opens access to a huge number of models, textures, scripts, and additions for Unity;
– the ability to use a completely free development environment MonoDevelop comes complete with Unity, which is an external IDE (for example, Microsoft Visual Studio or IntelliJ IDEA);

• disadvantages:

– Unity source code is closed and available only if you purchase an Enterprise license;
– problems will have to wait for updates and fixes, which sometimes takes quite a long time;
– lack of such a familiar concept as "game loop" or game cycle - there is no single point of entry, as in other engines, each game object can have a script or several scripts, its own set of events, and its game cycle;
– unusual and sometimes difficult to master visual editor, which can be a problem for novice developers.

2.2. Capabilities of available SDKs for developing augmented reality applications

SDK (Software development kit) – a set of development tools that allows software professionals to create applications for a specific software package, software basic development tools, hardware platform, computer system, game consoles, operating systems, and other platforms. The SDK takes advantage of each platform and reduces integration time [20].

All SDKs can be divided into two major groups [21]:

1. Created by developers for those who want to make an independent program or game. An example of such an SDK is DirectX, which is installed on almost any computer.
2. Self-sufficient tools. These include the Torque Game Engine SDK from Garage Games – a full-fledged gaming engine that supports the most advanced technologies. Unlike DirectX, with Torque you can create professional games without a deep knowledge of 3D programming technologies. Torque uses a C-shaped scripting programming language.

Let's make a comparative analysis of available SDKs (see table 2 and 3).

To determine the most optimal environment for the development of a mobile application, the method of expert evaluation was used [23].

To this end, the manifestation of each of the defined criteria for each of these development environments was checked, for which the experts were offered a corresponding questionnaire. A total of 20 respondents were involved (experts, deans of faculties, heads, and lecturers of departments of higher education institutions related to the IT field, as well as IT specialists).

Table 2

Overview of augmented reality SDK for iOS and Android [20]

SDK	Description	Supported platforms	Software features	Cost
Wikitude (see figure 1)	A paid platform for working with augmented reality.	Android, iOS, smart glasses.	Three-dimensional tracking technology based on SLAM, GEO Data; image recognition and tracking; cloud recognition.	Free trial. Full functionality starts from € 1990.
Vuforia (see figure 2)	One of the world's most popular platforms to help develop augmented reality.	Android, iOS, UWP and Unity.	Recognition of different types of visual objects (cube, cylinder, plane); text and environment recognition, VuMark (a combination of image and QR code); using Vuforia Object Scanner, you can scan and create object labels, Unity plugin is very powerful and easy to integrate.	Free. But there are also paid plug-ins that cost $ 99 a month.
Kudan	Vuforia's main competitor greatly simplifies augmented reality development.	Android, iOS.	Recognition of simple images and 3D objects provides easy database generation in the Unity editor.	The free version is for application testing only. The cost of a paid license is $ 1230.

To determine the degree of manifestation of each criterion, respondents were asked to evaluate its performance on a 4-point scale (from 0 to 3) [23]. The indicator was considered positive if the value of the arithmetic mean of its parameters was not less than 1.5 [23]. The degree of manifestation of the criterion was determined as follows: insufficiently manifested 0–50% of the indicators are positive; critical – 50–55%; sufficient 56–75%; high 76–100% [23].

Analysis of the available environments for the development of AR mobile application allowed to identify the following criteria and relevant indicators for their selection:

1. The *design criterion* characterizes the convenience, accessibility in use, and administration of the environment for the development of AR mobile applications:
   1.1. "accessibility" indicator means that the environment for the development of AR mobile applications in the presence of the Internet should be accessible to anyone, as well as anytime and anywhere,
   2.2. "multilingualism" indicator implies the presence in the environment for the development of AR mobile application support for different languages.
   3.3. "ease of use and administration" indicator implies that the environment for the development of AR mobile application should be easy to use, also provides convenience and clarity in use, organization of access, and more,
   4.4. "free of charge" indicator assumes the availability of a free tariff plan, which may not be fully functional,

Figure 1: Wikitude.

Figure 2: Vuforia.

    5.5. "multiplatform" indicator characterizes the environment for the development of AR mobile applications in terms of adaptation to use in different operating systems (Windows, Android, iOs, etc.).

2. The *functional criterion* characterizes the environment for the development of AR mobile application from a technical point of view, and provides for the presence of the following indicators:

    2.1. "recognition of different types of visual objects" indicator involves the recognition of different types of visual objects such as cube, cylinder, plane,

Table 3

Overview of augmented reality SDK for iOS and Android [20]

SDK	Description	Supported platforms	Software features	Cost
Maxst (see figure 3)	See [22].	Android, iOS, Windows, macOS.	Offers two different tools for pattern and environment recognition, database creation online through Tracking Manager.	The free version differs from the paid one only by a watermark. The PRO version costs $ 999.
Xzimg (see figure 4)	Represents three products for working with applications based on augmented reality: Augmented Face, Augmented Vision and Magic Face.	Android, iOS, Windows, WebGL.	Xzimg Augmented Face recognizes and tracks faces with Unity; Xzimg Augmented Vision recognizes and tracks flat images from Unity; Xzimg Magic Face is designed to replace facial features and apply makeup.	A free trial is only available for demonstration (inverts color and changes images). The paid version costs € 1600.
NyARToolkit (see figure 5)	Japanese augmented reality library based on ARToolKit.	Android, iOS.	Used only for image identification and tracking, easily integrated, but English version not available.	Free.
Metaio SDK	Library for creating augmented reality mobile applications.	Windows, macOS, iOS and Android	Uses OpenGL, SLAM methods for more accurate operation. Allows developers to use content without prior encryption to implement augmented reality in any application, offering modules for tracking three-dimensional objects, face recognition and tracking, infrared and laser tracking, advanced camera calibration, and transparent optics. No offline tools or server encryption are required to deploy 3D models and track data.	Free

2.2. "text and environment recognition" indicator characterizes whether the text and, accordingly, the environment will be recognized,

2.3. "combination of image and QR code" indicator involves the integration of the QR-code with the image,

2.4. "database creation" indicator characterizes whether it is possible to create databases

Figure 3: Maxst.

Figure 4: Xzimg.

in different ways.

Basic data on the indicators of the design criterion for each of the selected environments for the development of AR mobile application contains a table 4.

Basic data on the indicators of the functional criterion for each of the selected environments for the development of AR mobile application contains a table 5.

The generalized results are presented in table 6.

A review of alternatives based on the most important criteria showed that the most optimal
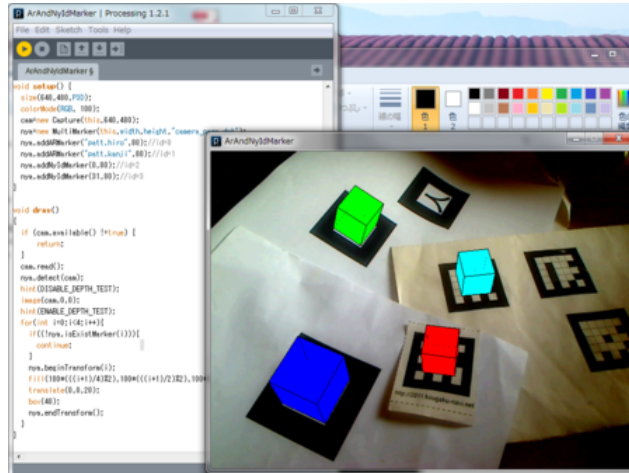
Figure 5: NyARToolkit.

Table 4

Design criterion of environments for AR application development and its indicators

Service	Indicators					Manifestation of the criterion
	1.1	1.2	1.3	1.4	1.5	
Wikitude	0.7	1.45	1.7	0.3	1.5	40%
Vuforia	2.5	2.25	2.45	2.15	2.8	100%
Kudan	1.45	1.85	2.7	0.25	1.45	40%
Maxst	2.1	1.45	2.25	1.45	2.2	60%
Xzimg	0.3	1.3	2.5	0.15	2.45	40%
NyARToolkit	2.3	0.2	2.4	2.6	1.4	60%
Metaio SDK	2.3	1.55	2.4	2.6	2.1	100%

environment for developing a mobile application is Vuforia [24]. Vuforia SDK is a mobile software that allows you to create augmented reality applications. It uses computer vision technology to recognize and track flat images and simple 3D objects in real-time.

The ability to register images allows developers to locate and orient virtual objects, such as 3D models and media content, in conjunction with real images when viewed through the cameras of mobile devices. The virtual object is oriented on the real image so that the observer's point of view on the object is correlated with their point of view on the image to achieve the main effect – the feeling that the virtual object is part of the real world. The developed augmented reality application allows virtual 3D objects to be superimposed on the video stream in real-time.

The application starts by initializing the camera, requesting a video stream, and selecting a frame from the stream. Next, you need to find the desired image on the selected frame, namely the marker. If a marker is found, the software uses a mathematical apparatus to calculate the camera's position relative to that marker. When the camera position is determined, the graphic model is displayed directly in that position. The graphic model is displayed on top of the video and is attached to the marker. As a result, the information is superimposed on top of the frame.

Table 5
Functional criterion of environments for AR application development and its indicators

Service	Indicators				Manifestation of the criterion
	2.1	2.2	2.3	2.4	
Wikitude	1.85	1	0	0.2	25%
Vuforia	2.85	2.7	2.7	2.8	100%
Kudan	2.5	0.4	0.6	2.35	50%
Maxst	1.95	1.45	1.1	2.1	50%
Xzimg	2.55	1.6	0.4	0.8	50%
NyARToolkit	1.8	0.55	0.45	0.3	25%
Metaio SDK	2.65	2.7	0.9	0.9	50%

Table 6
The results of selection of the environment for development of AR of the mobile application on manifestation of all criteria are generalized

Service	Criterion	
	Design	Functional
Wikitude	40%	25%
Vuforia	100%	100%
Kudan	40%	50%
Maxst	60%	50%
Xzimg	40%	50%
NyARToolkit	60%	25%
Metaio SDK	100%	50%

If the marker is not detected, the frame is re-selected from the video stream.

3. Conclusions

There is no single approach to the choice of a tool for the development of augmented reality technologies, different authors characterize their choice based on the number of supported platforms, ease of transferring code to different platforms, performance, and more.

Depending on the purpose of the application, you can use not only cross-platform engines but also sets of development tools. Such kits allow you to speed up and simplify the process of developing any program with elements of augmented reality. These advantages and disadvantages will help beginners to choose the most convenient tool for developing augmented reality technologies.

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