Development of mobile applications of augmented reality for projects with projection drawings

Oleksandr V. Kanivets[1[0000-0003-4364-8424]], Irina M. Kanivets[1[0000-0002-1670-5553]], Natalia V. Kononets[2[0000-0002-4384-1198]], Tetyana M. Gorda[3[0000-0002-6924-0219]] and Ekaterina O. Shmeltser[4]

[1] Poltava State Agrarian Academy, 1/3, Skovorody Str., Poltava, 36003, Ukraine
k.alex2222@gmail.com, ira.gorda80@gmail.com
[2] Poltava University of Economics and Trade, 3, Koval Str., Poltava, 36014, Ukraine
natalkapoltava7476@gmail.com
[3] Poltava Polytechnic College, 83a, Pushkin Str., Poltava, 36000, Ukraine
gtatana343@gmail.com
[4] Kryvyi Rih Metallurgical Institute of the National Metallurgical Academy of Ukraine, 5, Stephana Tilhy Str., Kryvyi Rih, 50006, Ukraine

Abstract. We conducted an analysis of the learning aids used in the study of general technical disciplines. This allowed us to draw an analogy between physical and virtual models and justify the development of a mobile application to perform tasks on a projection drawing. They showed a technique for creating mobile applications for augmented reality. The main stages of the development of an augmented reality application are shown: the development of virtual models, the establishment of the Unity3D game engine, the development of a mobile application, testing and demonstration of work. Particular attention is paid to the use of scripts to rotate and move virtual models. The in-house development of the augmented reality mobile application for accomplishing tasks on a projection drawing is presented. The created mobile application reads, recognizes marker drawings and displays the virtual model of the product on the screen of the mobile device. It has been established that the augmented reality program developed by the team of authors as a mobile pedagogical software can be used to perform tasks both with independent work of students and with the organization of classroom activities in higher education institutions.

Keywords: virtual model, augmented reality, mobile application, Unity3D, Vuforia, testing, resource-based learning, mobile learning.

1 Introduction

1.1 The problem statement

Now the tendency of the rapid development of computer tools and digital technologies, their widespread adoption in all spheres of public life, the desire of students to widely apply them in everyday life and professional activities, actualize the need for their use in the educational process [2; 4; 10]. In recent years, digital technology has made a huge leap in the development and expansion of areas of use. Augmented Reality (AR) is an environment which combine the physical world objects with digital data in real time using mobile Internet devices (MID), as well as software for them. If earlier this technology was used mainly in the military industry and computer games, now AR penetrates almost all spheres of human social activity: economics, medicine, education, architecture, advertising, etc. [30].

Thoroughly studying the problem of organizing mobile learning (m-learning), domestic and foreign scientists Luke Bennett [5], Valerii Yu. Bykov [4; 3], Baiyun Chen [5], Abdel Rahman Ibrahim Suleiman [13], Oksana M. Markova [17], Natalia V. Moiseienko [26], Pavlo P. Nechypurenko [18], Olena O. Pavlenko [19], Kristine Peters [20], Oleksandr P. Polishchuk [31], Maryna V. Rassovytska [22], Serhiy O. Semerikov [24; 25], Ryan Seylhamer [5], Andrii M. Striuk [29], Illia O. Teplytskyi [27], Viktoriia V. Tkachuk [32] note that the introduction of mobile learning with MID is an effective way for students to gain knowledge, develop information skills, as well as a unique form of vocational training and maintaining the productivity of the learning process while a student it is independent of time, place and space.

The main task in the vocational training of first-year students of technical specialties is the development of spatial thinking for quality reading of drawings, drawing skills, memorization and systematization. To do this, use various learning aids, such as diagrams, photographs and technical drawings. Basically, it is quite difficult to teach students to read drawings, which is associated with the need to develop orientation skills in 3D space and spatial imagination. This requires additional efforts from students to visualize objects in different projections and orientations (axonometric perspective geometry), as well as to manipulate imaginary 3D models to create two or three flat views. Thus, in educational institutions it is customary to use 3D physical objects or other models as additional learning tools.

3D physical models (Fig. 1) are used in the learning of Engineering Graphics and Descriptive Geometry, Engineering and Computer Graphics et al.

A typical example is the use of 3D physical models to solve metric and positional problems in descriptive geometry, which help students look at solutions from different perspectives and improve the understanding of the relationship between a real object and a two-dimensional image [6].

The use of physical models also has several disadvantages, such as: high cost, which leads to the purchase of models only from the basic topics of the discipline. In the process, models wear out and break their parts, and sometimes, due to inadvertence and difficulty in moving, entire models are destroyed. Usually, physical models belong to educational institutions and require special storage, which in turn makes it impossible for a student to constantly have free access to objects. These and other factors limit the possibility of the full use of models in the educational process.

To solve these problems, it is advisable to use virtual models of products. They are easily using on MID with AR. But some scientists [1; 7] emphasize the importance of using physical models in the educational process, justifying this by lowering the prices of digital manufacturing technologies, such as 3D printers.

Fig. 1. 3D physical models in teaching projection drawing

1.2 Theoretical background

AR attracts a lot of attention in education. In our study, mobile learning is understood as a form of resource-based learning and is considered as a system of organizational and didactic activities based on the use of mobile ICT. Undoubtedly, the problem of developing such mobile pedagogical software tools that will improve the quality of professional training of specialists, in particular, technical specialties, is also becoming relevant now [16].

A number of scientists [1; 7; 9; 23] provide comparative data on the use of physical and virtual models. After analyzing the possibility of replacing the physical (material) model with a 3D virtual one when studying the drawing course, the scientists recorded that the students did not feel any discomfort when working with electronic models.

The use of 3D virtual models makes it possible to level out some negative factors that have real physical models, such as breakdowns or damage, since a mobile application that demonstrates virtual models can be effectively used with MID. The problems of transportation, storage and exchange of learning equipment outside the laboratory are also solved, in connection with the possibility of their placement on cloud media or virtual training classes on the Internet.

The display of digital models on MIS, as a rule, is based on the capabilities of AR, which attracts more and more attention of the educational community. Unlike multimedia and virtual reality (VR), AR reflects virtual objects as holograms superimposed on the real world [28]. Most of the published studies in the field of AR are presented on promising technologies (imaging, passive visualization), there are also applications on experimental prototypes with an active interface [12].

1.3 The objective of the article

Consider the methodology for creating mobile applications using AR technology and present your own development to perform tasks on a projection drawing.

2 Results and discussion

We performed the development of AR mobile application on a laptop with the following characteristics: processor Intel Core i7-3520M, RAM 12 GB, video card Intel HD 4000, web camera and network card with Windows 7 Ultimate (64-bit version).

At the beginning of development, it is necessary to design all models. While the mobile application is running, virtual models that are better developed in a CAD program are displayed on the phone screen.

This mobile application is being developed to study the Engineering Graphics or Descriptive Geometry, Engineering and Computer Graphics using Compass 3D, AutoCAD, Inventor, Solidwork, 3ds Max, Cinema4d or Maya.

The above software product is paid and for their use it is necessary to have the appropriate knowledge and skills. Therefore, in the project we used an open source program – Blender [23].

The next stage of development is the installation and configuration of Unity3D. Download the free version 2017.3.1f1 (64-bit) for Windows of the Unity3D game engine from the official site [33]. During the installation, in addition to the Unity3D and MonoDevelop, we also note the Android Build Support and Vuforia Augmented Reality [21] support, which are necessary for developing and compiling augmented reality programs in the Android system.

We are developing an AR application using the Vuforia AR platform. To use it, you must register for free on the official website. This makes it possible to download the software and get an access key. In the account in the target manager, create a new database. Upload target images to the new database. Each target image is processed by means of computer vision and a rating is set (Fig. 2).

Fig. 2. Vuforia Target Image Recognition System

The best images have five stars. They will be quickly and efficiently allocated by the application. The minimum recommended value is three stars. A fully formed database of target images is loaded into Unity3D.

Unity starts with a dialog box for creating and storing a new 3D project. The user dialogue with the Unity3D game engine is possible using the Visual editor and C# programming language.

The Visual editor consists of a Scene, a window in which all the models used in the program are displayed; Inspector – a panel for setting properties of Project commands – an analogue of Explorer in Windows; hierarchy window – a window with a list of all project objects.

Since we are developing the AR program for the Android platform, we therefore additionally install and configure the Android SDK [8] and JDK [14]. These are free products from Google and Oracle, the latest versions of which can be downloaded from official sites.

We begin the development of a mobile application with video tutorials on building a cam. We took the video from the lessons of Anna Veselova [34]. In the hierarchy window, replace the standard camera with AR. On the scene we add the target image of the cam, which is a child of the AR camera. Using the Component – Video – Video Player command, we create funds for playing a video resource, which already has a start and pause button (Fig. 3).

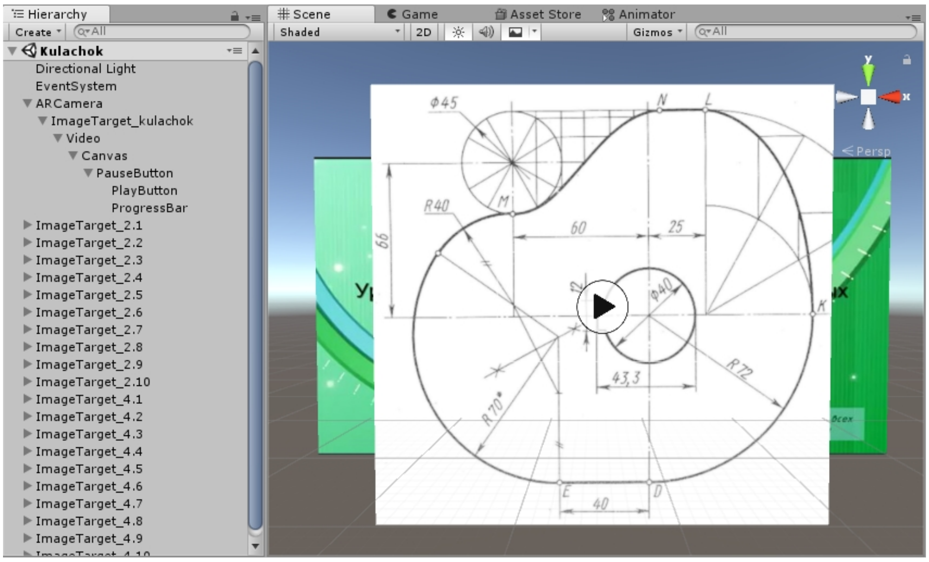

Fig. 3. Video resource development

We begin the development of the main part of the program by downloading ImageTarget and the most virtual models (Fig. 4). Thus, the program through the phone's camera, having scanned the correct figure, will show the correct model on its screen.

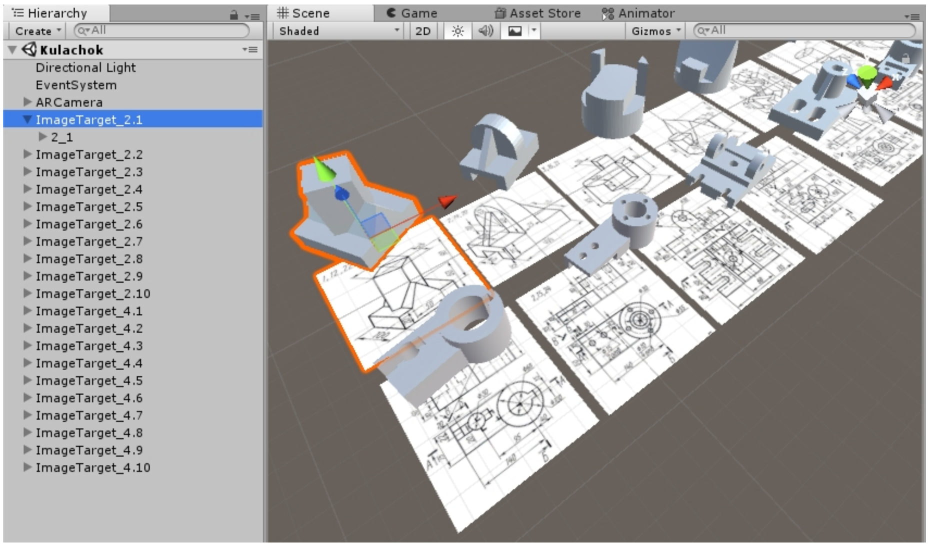

Fig. 4. Download ImageTarget and its model

The model is controlled using the fingers of a user who can move and rotate it. Such work is ensured thanks to new components – scripts that will indicate the action to perform when they are activated. In our project, we used open source scripts provided by Carlos Wilkes in the free Lean Touch project [35]. For example, the scenario for moving the model on the phone screen is as follows:

```
using UnityEngine;

namespace Lean.Touch
{
  /// <summary>This script allows you to translate the current
  /// GameObject relative to the camera.</summary>
  [HelpURL(LeanTouch.HelpUrlPrefix + "LeanTranslate")]
  public class LeanTranslate : MonoBehaviour {
    [Tooltip("Ignore fingers with StartedOverGui?")]
    public bool IgnoreStartedOverGui = true;
    [Tooltip("Ignore fingers with IsOverGui?")]
    public bool IgnoreIsOverGui;
    [Tooltip("Ignore fingers if the finger count doesn't match?
(0 = any)")]
    public int RequiredFingerCount;
    [Tooltip("Does translation require an object to be
selected?")]
    public LeanSelectable RequiredSelectable;
    [Tooltip("The camera the translation will be calculated
using (None = MainCamera)")]
```

```
    public Camera Camera;
#if UNITY_EDITOR
    protected virtual void Reset()    {      Start();    }
#endif
    protected virtual void Start()    {
      if (RequiredSelectable == null)
        RequiredSelectable = GetComponent<LeanSelectable>();
    }
    protected virtual void Update()    {
      // Get the fingers we want to use
      var fingers =
LeanSelectable.GetFingers(IgnoreStartedOverGui, IgnoreIsOverGui,
RequiredFingerCount, RequiredSelectable);
      // Calculate the screenDelta value based on these fingers
      var screenDelta = LeanGesture.GetScreenDelta(fingers);
      if (screenDelta != Vector2.zero)      {
        // Perform the translation
        if (transform is RectTransform)
          TranslateUI(screenDelta);
        else
          Translate(screenDelta);
      }
    }
    protected virtual void TranslateUI(Vector2 screenDelta)    {
      // Screen position of the transform
      var screenPoint =
RectTransformUtility.WorldToScreenPoint(Camera,
transform.position);
      screenPoint += screenDelta; // Add the deltaPosition
      // Convert back to world space
      var worldPoint = default(Vector3);
      if
(RectTransformUtility.ScreenPointToWorldPointInRectangle(
transform.parent as RectTransform, screenPoint, Camera, out
worldPoint) == true)
        transform.position = worldPoint;
    }
    protected virtual void Translate(Vector2 screenDelta)    {
      // Make sure the camera exists
      var camera = LeanTouch.GetCamera(Camera, gameObject);
      if (camera != null)      {
        // Screen position of the transform
        var screenPoint =
camera.WorldToScreenPoint(transform.position);
        // Add the deltaPosition
```

```
        screenPoint += (Vector3)screenDelta;
        // Convert back to world space
        transform.position =
camera.ScreenToWorldPoint(screenPoint);
      }
      else
        Debug.LogError("Failed to find camera. Either tag your
cameras MainCamera, or set one in this component.", this);
    }
  }
}
```

According to the method described above, we add all the models and scripts to the program, as well as compile the installation file for the Android system. The work and the main features of the mobile application can be seen on the demonstration video [15].

The next stage in the development of any program is testing. The developed mobile application was tested on the following Android-based mobile devices:

1. Samsung Galaxy A5 A520F – Android 8.0.0; 5,2"; 1920x1080; Exynos 7880 Octa; 16 MPx camera; RAM 3 GB;
2. Xiaomi Redmi Note 4x – Android 7.0; 5,5"; 1920x1080; Qualcomm Snapdragon 625; 13 MPx camera; RAM 2 GB;
3. Xiaomi Redmi 4x – Android 7.1.2; 5,0"; 1280x720; Qualcomm Snapdragon 435; 13 MPx camera; RAM 2 GB;
4. Lenovo S8 A7600 – Android 5.0; 5,3"; 1280x720; MT6592M; 13 MPx camera; RAM 2 GB;
5. Lenovo A6010 Pro – Android 5.0; 5,0"; 1280x720; Cortex-A53; 13 MPx camera; RAM 2 GB.

It is necessary to check the display of models, the operability of their movement and rotation with the touch of a finger on the screen, playing the training video and the sound. According to testing results, we can conclude that the program works correctly on phones with Android 5.0 system and on newer systems, regardless of processor type, screen matrix and RAM size.

Thus, we have developed a mobile application, which reads, recognizes the image marker and displays an model of a product on the MID screen that can be moved or rotated with the touch of a finger. After receiving the input information and its processing, the program inserts the corresponding 3D model into the real image displayed on the screen of the MID.

Moreover, the 3D virtual object is correctly located relative to the marker and interacts with it according to the given rules: for example, it is tilted along with the marker printed on the textbook or manual page. At the same time, moving the textbook, you can consider the model of the product in different angles and scales.

The designed AR app allows to implement a number of important tasks of the modern educational process: thanks to the capabilities of 3D modeling, visualize solutions to key problems (teach students how to read and execute working drawings and sketches, assembly drawings, schematic images, build virtual models) when students majoring in engineering study the Engineering graphics, Descriptive geometry, Engineering and Computer graphics, Mathematics, Physics, Theoretical Mechanics, Resistance of Materials, Theory of Mechanisms and Machines [11], within the framework of which 3D physical models are used; help students better understand complex structures and complete tasks that require spatial imagination and developed spatial thinking, which are the basis for the successful implementation of future professional activities of students majoring in engineering; provide students with the opportunity to master practical skills, research experience using their own MID; increase the motivation for learning and the effectiveness of independent work of students, making learning a bright and interesting process; create a new generation of mobile learning tools in the context of the implementation of the concept of resource-oriented education of students in higher education.

3 Conclusion

Thus, in the statement of the problem, we substantiated that a person equally perceives both physical and virtual models, but virtual models have some advantages over physical ones, thereby proving the desirability of describing the methodology and creating applications for MID using AR technologies.

The analysis of programs for 3D modeling made it possible to substantiate the choice of open source software. The main points of installing the game engine Unity3D and additional components, including the AR platform Vuforia, are shown. The stages of the development of the scenes were given. Particular attention is paid to writing detaily commented scripts. The finished program was tested by students on mobile phones with various technical characteristics when performing tasks on independent work and preparing for classroom studies in Engineering Graphics and Descriptive Geometry, Engineering and Computer Graphics. And also a demo video was created showing the operation and main features of the program. Demonstrated experience in the development of AR programs with engineering graphics will be useful to the pedagogical community for writing their own applications.

This article describes a methodology of application developing for MID using AR technology on one topic of an engineering graphics course. In the future, we plan to create full-fledged electronic systems (handbooks), including tests and tasks for self-testing, from the most difficult topics, such as the formation of projection images, simple and complex cuts, types and formations of threads, detachable and integral connections, and others.

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