Research and software development using AR technology

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Abstract. The paper considers programs and devices of augmented reality, examines the general environments and methods of software development and the rationale for their selection. The work describes in detail the operating principle of the software, the pattern recognition algorithm, the UML class diagram, the UML usage diagram, and the architecture of the 3D rendering engine and a description of its operation. An example of practical application of software with pattern recognition is offered. The paper examines the impact of virtual reality on human health, as well as the problem of assimilation of educational material in preschool education. To solve the problem, various algorithms for the program are proposed. Based on the conducted studies, it was decided to create the software for the experiment on the basis of developed algorithms for preschool education. The results of the work can be used for further research in the field of expanded reality, for new developments in this field and improvement of the quality of education.

1. Introduction

The mobile market shows high growth rates [1], with gadget users becoming not only adults but also children. This is the reason for the rapid development of the mobile application market for children's audiences. A separate segment of this market is software for mobile devices using the technology of augmented reality. Augmented Reality (AR) – a technology that allows you to combine the virtual world with the real, integrating virtual objects in real time [2].

Augmented reality can change the perception of the modern world and make it more convenient and interactive. The spheres of application of this technology are endless, it all depends on the person's imagination, this can be medicine, military science, education, the sphere of state services, etc. The fact is that augmented reality, unlike virtual reality, complements the real world with virtual objects, rather than replacing it. This means that AR requires direct user contact with reality through additional content, which greatly simplifies the solution of certain tasks.

When considering the interaction of children with gadgets, it should be borne in mind that in France in 2013 the Academy of Sciences published the book "The Child and the Screens" (L'enfant et les écrans) [3], which discusses the interaction of children and gadgets with the results of recent work in medicine, neurology and psychology. Here it is described that the child can be allowed to use smartphones with 1.5 years.

According to studies conducted by Common Sense Media across the United States, as early as in 2011, 38% of children from 0 to 8 years used mobile devices for watching video and games [4], but in 2013 their number increased to 72% [5]. The latest study of 2017 notes that to date, 84% of children of the age under consideration are actively using mobile devices [6].

In 2015, the expert project Hi-Tech.Mail.Ru conducted a survey in Russia among more than 5,000 parents. According to the results of the survey, it became clear that children begin to use gadgets for the first time between the ages of 1 and 3, with 85% of parents giving out "smart" adults to children.
Also during the survey, it was found that 66% of children use gadgets for entertainment, and 20% – use smart devices for training.

Taking into account the above-described indicators, it can be concluded that today the implementation of software with augmented reality for mobile devices is actual in the educational process. In this case, it is not necessary to replace books familiar to parents and children, on the contrary, this technology will allow to expand the possibilities for studying them. Thus, the methodology of teaching does not change radically, but at the same time, children receive a complete presentation of the material and its assimilation.

2. **Formulation of the problem**

The problem is that traditional methods of learning do not work effectively on the assimilation of information through oral speech and text. The human brain is more inclined to process visual images than a simple text. On this subject, there are many studies [7], which show that the technologies of augmented reality in the field of education enrich the visual and contextual learning, improving the content of information. If 25% of information is retained while listening to lectures in short-term memory, then this number reaches 80% with visual training. To date, the implementation of various methods for visualization and gaming of education is topical, and the use of augmented reality in the sphere of education will only benefit people, especially children. This technology will not only develop associative thinking, but also increase the effectiveness of mastering the educational material. Existing mobile applications are similar in content and are not of great interest, since they do not use the technology of augmented reality. In addition, the existing software for preschool children using the technology of augmented reality is aimed at a certain area of knowledge and requires additional paid printed materials (books, magazines, etc.). There is a need to develop software for preschool education using AR-technology, which allows to increase the level of mastering of educational material in preschool education, which proves the relevance of this work.

In this regard, the purpose of this work is to increase the level of learning material in pre-school education by developing software for interactive visualization of educational material using algorithms of augmented reality. Using this technology, you can deliver the material necessary for learning in a more interesting and accessible form for students, building an activity on the basis of fascinating games and demonstrations. The convenience of using virtual 3D-objects simplifies the process of explaining new material. At the same time, mastering the technology of augmented reality, the level of information literacy of parents and their children.

To achieve this goal, an analysis of the subject area was carried out, which showed that to date there is no comprehensive software with augmented reality for the education of children on the market. In this regard, applications that are available on the Russian market for mobile phones on the iOS platform, in which the augmented reality is used for the education of children, were considered. To work with the programs in question, only a smartphone with a built-in camera is required and no additional equipment, for example glasses, is required. It is important to note that for each software reviewed, printed material is required from which the camera of the device will read the markers and then display its content. However, some of the applications require the purchase of a printed publication, while for others it is sufficient to print materials at home.

In the course of the analysis (Table 1), it turned out that for children there are not so many training applications with augmented reality, despite the fact that demand for them is growing. At the same time, educational programs are divided into two categories: teaching the alphabet and the mathematical account. As for applications with ABC, there are at least 3 programs, but for them you need to purchase additional content. It should also be noted that among the programs found Russian-language content is only - Devar kids and Live ABCs 3d. Programs for studying mathematics in which the technology of augmented reality is used also do not represent such a wide variety, there is not even a single software in Russian, and only AR Flashcards software is used to teach young children under 5 years of age.
Table 1. Comparative analysis of existing software with augmented reality

| AR Flashcards – Animal Alphabet | Devar kids | 3D live alphabet | Maths Teach-AR | FETCH! Lunch Rush | AR Flashcards | Funny lessons |
|---------------------------------|------------|-----------------|----------------|------------------|---------------|--------------|
| Cost of the full version (rub) | -          | -               | -              | 379              | -             | 299          |
| Built-in purchases              | -          | +               | -              | -                | -             | +            |
| Free additional printed material| +          | -               | +              | +                | +             | +            |
| Age (years)                     | to 5       | 4+              | to 5           | 12+              | 6-8           | to 5         | to 7         |
| Sound Assistant                 | -          | -               | +              | -                | +             | -            | +            |
| Russian language support        | -          | +               | +              | -                | -             | +            |
| Subject                         | Alphabet   | Mathematics     | Mathematics,   | Alphabet etc.    |               |              |

That is why it is important to create a comprehensive application for children in Russian, in which augmented reality will be used both for studying mathematics and for the Russian language, namely, alphabet. The presented comparative analysis (Table 1) showed that the new software will be unique and have the advantage of Russian-speaking users.

3. Methods for solving the problem
To solve the problem, various algorithms for the program are proposed. Based on the conducted studies, it was decided to create the software for the experiment on the basis of the developed algorithms called "Funny lessons" for teaching children, where for today there are two sections: "Mathematics" and "Alphabet", for the study of numbers and letters, respectively.
The software consists of the following components:
1. The main menu that meets the user and provides access to the instructions for working with the software, a page with general information about the product and authors, and also directly to work with a conventional camera and a stereo camera;
2. «Start» – window for selecting a section;
3. «Mathematics» – window of work with the AR-camera for the study of figures;
4. «Alphabet» – window for working with AR-camera for studying letters;
5. The window for working with a stereocamera in the section «Mathematics»;
6. Window for working with a stereocamera in the section «Alphabet»;
7. «How to play» – a window containing instructions for working with the program;
8. «About» – a window of general information about the application and about the authors.
A more detailed structure of the software is shown in Fig. 1.

**Figure 1. Software structure**

The class diagram of the software being developed is shown in Fig. 2. It should be noted that the VuforiaBehavior class is the main class of the software, since it initializes all the main packages, in addition, this class is responsible for tracking and controlling the camera.

**Figure 2. UML class diagram**
In Fig. 3 is a UML diagram of use cases.

![UML Diagram]

**Figure 3.** UML diagram of use cases
The blocks shown in Fig. 4 and Fig. 5, expand the software architecture, providing more detailed information about the 3D rendering module.

**Figure 4.** The architecture of the 3D rendering block

**Figure 5.** 3D rendering pipeline
The UML state diagram displays the algorithm of the software operation, describing possible sequences of states and transitions (Figure 6).

Figure 6. UML state diagram
A more detailed algorithm for the operation of the software can be found in Fig. 7.

Figure 7. Algorithm of software operation
In the software, augmented reality is realized. For this purpose, the following steps were taken (Fig. 8) for image recognition and implementation of the corresponding digital content:

1. Capturing images from the real world, using the camera, each frame is captured and transferred to a tracker.
2. Next, the image converter that changes the format of the captured image provided by the camera into a format suitable for rendering OpenGL ES and for subsequent binding to the displayed materials.
3. In the tracker, using computer vision algorithms, image recognition occurs.
4. At this time, the software code must regulate all the work and update the application logic with each new input data.
5. Computer vision algorithms compare the resulting image from the camera with an existing marker database.

![Image Recognition Algorithm](image)

**Figure 8. Image Recognition Algorithm**
4. Experiment

Since the software being developed is oriented towards the children's audience, it was decided to make a simple interface and animation of the augmented reality models to attract children to the learning process, which was successfully implemented with the help of Unity and scripts in C#.

Simulation of the animation (Figure 9) took place in the Unity editor using the Animation component.

Then the voice acting of the animation was recorded and reproduced. An example of a function that plays animation and sound when you press a virtual button:

```csharp
public void OnButtonPressed(VirtualButtonAbstractBehaviour vb) {
    Debug.Log("button pressed");
    Apple_1.GetComponent<Animation>().Play();
    Apple_2.GetComponent<Animation>().Play();
    Apple_3.GetComponent<Animation>().Play();
    Apple_4.GetComponent<Animation>().Play();
    Apple_1.GetComponent<AudioSource>().Play(34080);
}
```

Function, to stop all audio components:

```csharp
private AudioSource[] allAudiosources;

void StopAllAudio()
{
    allAudiosources = FindObjectsOfType(typeof(AudioSource)) as AudioSource[];
    foreach (AudioSource audioS in allAudiosources { audioS.Stop();
}
```

Moreover, the interaction of the user with virtual objects was realized. It was also decided to make an assignment to the picture on the "Press" marker, the OnButtonPressed() function. For this it was necessary to make an animation for each scene object, as well as create a virtual button with the following parameters:

```csharp
private GameObject vbButtonObject;

void Start()
{
    vbButtonObject.GetComponent<VirtualButtonBehaviour>().RegisterEventHandler(this);
}
```

To reduce the waiting time for the user to load the camera for augmented reality, a function was implemented that, during the loading of a new level, shows the download window:
The experimental testing of the developed algorithms was carried out, which showed the operability of the software. In Fig. 10 shows an example of the work of image recognition and the implementation of digital content. Software using the camera of the mobile device reads the image, compares it with the loaded database and when the markers match, they display the corresponding digital content.

![Marker recognition and visualization of digital content](image)

**Figure 10.** Marker recognition and visualization of digital content (on the left – before, on the right – after)
Also, a functional was implemented that reproduces the animation of objects when pressed (Figure 11). When you click on the "Start" button, the animation is played, which ends when the corresponding image is lost and starts again, if you press the button again. Also when the button is pressed, the sound is played.

Figure 11. Realization of animation after interactive interaction

The interface realization function in stereopair mode for the virtual reality helmet was tested (Fig. 12). The software functions do not differ from the standard mode, when the button is pressed, animation and sound are played.

Figure 12. An example of the application operation in stereopair mode for the virtual reality helmet
5. Conclusion
As a result of the work carried out, it was shown that augmented reality is an effective tool for creating software in the field of education. This technology allows filling printed materials with digital three-dimensional content, which simplifies the learning process and increases the interest of children in textbooks and books.

As part of the work, the need to create software using the technology of augmented reality for preschool education is identified. Algorithms for the operation of software, natural human-computer interaction have been developed. The efficiency of the developed algorithms is confirmed by the results of experimental testing.

The offered software is expedient for applying in education of children for development at children of associative thinking and increase of level of mastering of a teaching material. Possible ways to improve the effectiveness of preschool education by adding the opportunity to work in glasses augmented reality, subject to the creation of special glasses for children.

6. References
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