Methodical procedure for creating content for interactive augmented reality

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***Abstract*— The article describes a methodological procedure for the development of interactive applications in augmented reality (ARIT) by demonstrating it on a life-size 3D hologram of engineering equipment. In this article, we consider the creation of a general application model using the Unity 3D game engine for development for the Head mounted display (HMD). We used the Hololens device to display a demonstration of the model we created and for analysis problems faced during the initial development of interactive content in mixed reality.**

I. Introduction

Interactive Augmented Reality (ARIT) represents a more advanced concept enabling direct or indirect interaction with content, a space enriched with digital, sound or image data that provides a new dimension of understanding a product or service in a real environment as defined by van Krevelen et al. [1] Unlike virtual reality, which replaces a real simulated environment, a synthetic environment that makes it impossible for users to perceive the environment around them [2] ARIT, using a 3D virtual model, an authentic experience with full-value information in a real environment or also in a virtual environment, which includes the concept of mixed reality, of which ARIT is a part. [7]

The developers put as much emphasis as possible on creating an interactive multi-sensory experience with broad integration in various areas of education, training, up to the sale of goods and services, comparable to the real acquisition of stimuli from the product during the development of ARIT.

II. Components

As described by Vallino [13] the goal of augmented reality systems is to combine the interactive real world with an interactive computer-generated world in such a way that they appear as one environment.

Interactivity consists in the creation of a complex system of software and hardware, which makes it possible to have digital virtual outputs in a real environment. The quality of holograms is a result of good environment and good app development. [11] AR systems must perform tasks such as *tracking, sensing, displaying, and interacting* (Fig.1) which can be supported by rapid prototyping frameworks that evolve independently of their applications. [10]

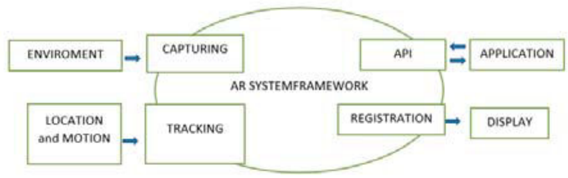

Figure 1. AR System Framework

A. HARDWARE

In the past decade, AR research efforts have successfully tackled several challenging hardware integrations problems, [12] so that current AR systems are beginning to function robustly.

The hardware part of a complex system for creating interactive content in AR/MR consists of the following basic components:

- *computer infrastructure,*
- *display,*
- *associations,*
- *relationships,*
- *connections.*

Computer infrastructure: Ensures generation and management of virtual objects and their materials that will be inserted into a real or mixed environment, processing of tracking information and control on the device screen. Includes important tagging and tracking technologies with multiple tracking systems and hybrid tracking systems to address registration issues. Unlike the virtual environment of an AR tracking device, it must have higher accuracy, a wider range of inputs and bandwidth, and longer ranges. [3]

Sensor systems- They form components like [14] gyroscopes, GPS, electronic compasses, cameras, microphones.

Accelerometers and gyroscopes are source less inertial sensors, usually part of hybrid tracking systems and are built into, for example, [15] mobile devices, which subsequently do not require a prepared environment for AR/MR display. Timed measurements can

provide a practical dead reckoning method for position estimation combined with accurate heading information.

Display: Displays are image-forming systems that apply a set of optical, electronic, and mechanical components to generate images somewhere on the optical path in-between the observer's eyes and the physical object to be augmented. Depending on the optics being used, the image can be formed on a plane or on a more complex non-planar surface. [4] [28]

Display systems - consist of devices such as Head Mounted Display, mobile phones with built-in camera and handheld devices and computers and are required to display computer generated content. [4]

Figure 2. (4) shows the basic categorization of displays relative to the observer and the real object*: on the head, in the hand and in space.*

Relationships: serve to create relations and connections between real objects and virtual elements.

Connections: connection to the Internet network, and as a communication gateway between several users. [4] *Wireless* connections and related protocols for real-time augmentation settings and allowing multiple users to interact in real-time to subsequently create the Metaverse, which can be defined as a post-reality universe. [16] It creates an eternal and persistent multi-user environment that combines physical reality with digital virtuality. It is based on the convergence of technologies that enable multisensory interactions with virtual environments, digital objects, and people.

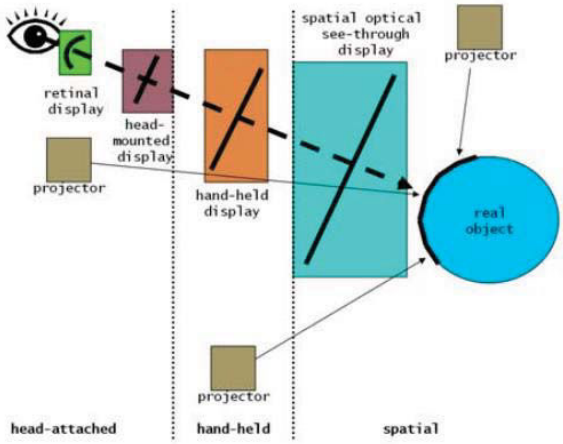

Figure 2. Image-generation for augmented reality displays.

B. Framework

MR application development is a complex and complicated process consisting of a multi-step implementation. A key question in designing such an application is increasing level of user interaction. Based on a study by Rokhsaritalemi et al. [17] who proposes a comprehensive framework consisting of necessary components for MR applications, we have shown a simpler, more general model described in Figure 3

ENVIRONMENT

The environment can be easily divided into external and internal. Interactive augmented reality is mainly created for the indoor environment to achieve the most intense experience with the elimination of disturbing elements of the external environment.

To record a 3D object in space, the device must be able to *track and map* the surrounding environment. Several technologies are used for positioning, such as: *GPS, image tracking, motion tracking (SLAM), face and object tracking, and environmental understanding*.

Interactive augmented reality and mixed reality applications require a thorough knowledge of the relative positions of the camera and the scene. When any of them moves, it means tracking in real time all six degrees of freedom (6 DOF) that define the position and orientation of the camera relative to the scene, or equivalently, the 3D displacement of the object relative to the camera. [6]

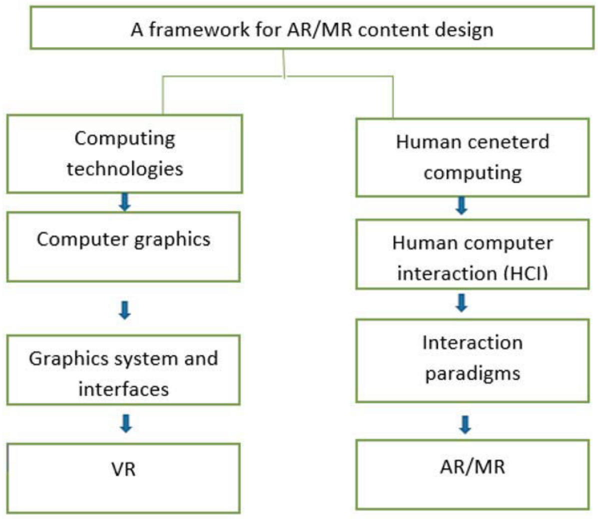

Figure 3. Framework

Vision-based 3D tracking involves image processing to obtain the necessary information and position estimation, for which multiple means are used such as fiducials, referred to as landmarks or markers. [21] There are many types of reference markers, and the more advanced ones allow real-time position refinement, which is highly desirable for ARIT and mixed reality technologies.

The goal of *human-centered computing* [19] is to create technologies that better meet human needs in interaction with the digital world through the study of people's needs. Using different research methods from the social sciences, it is possible to push the boundaries of knowledge between interaction with the virtual and real world.

Human Computer Interaction (HCI) mainly deals with human aspects perception, cognition, intelligence, sense-making and, above all, interaction between man and machine [18] which leads to the creation of an immersive experience.

III. DEVELOPMENT OF APPLICATION IN ARIT

Before starting the development of applications in interactive augmented reality, it is necessary to set basic goals, choose the right device for which the application will be developed and the program in which it will be written.

For a more intense experience, it is advisable to focus mainly on HMD devices that allow users to have free hands, so they can interact by touch in a free space.

In this article, we consider the creation of a generic application model using the Unity 3D game engine for development known as the AR Foundation toolkit. We also point out an inappropriately chosen CAD system for drawing mechanical equipment using SolidWorks software, the AR Foundation provides a frameless device SDK for features specific to device provided by Google Ar core, Apple ARkit, MS Hololens, Magic Leap [9] and others, thanks to which we chose this universal tool in our article

A. Content

The creation of content in interactive augmented reality for HMD is a rather widespread topic that includes countless alternatives, so we will describe only the basic pillars of building your own content.

The placement of AR content in relation to the display strongly influences the impression of a seamlessly integrated system. [6] To meet the requirements of an immersive modeling environment, it is necessary to create models and manipulate them [6] which can be achieved especially with high-quality, perfectly illustrated, and interactive graphics.

B. Demonstration on the created life-size model

Instead of a simple model, we decided to demonstrate a complex geometric model of hydraulic shears created by CAD software.

The following part consists of the concept of creating your own model and pointing out the inappropriate direction in the creation of immersive models.

In Fig. 4. is a geometric model that was made using 3D CAD software Solidworks, preferably intended for the engineering industry.

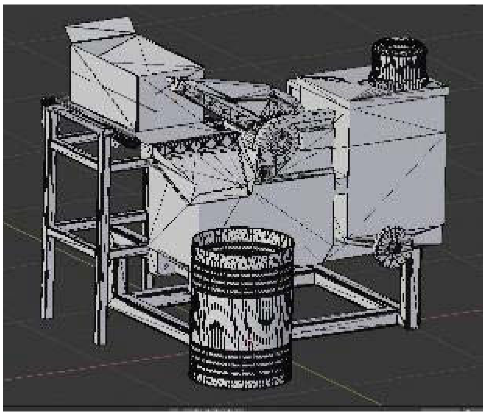

Figure 4. CAD model in full size of polygons

This software is not a suitable alternative for creating interactive content as it contains many polygons that require a lot of computing power. The solution is the reduction of polygons, adding textures as can be seen in Fig. 7.

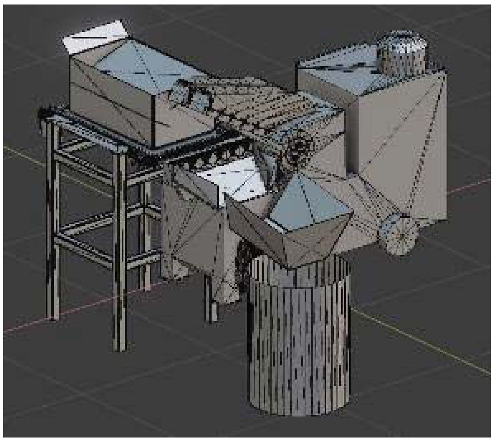

Figure 5. CAD model of hydraulic shears with initial reduction of polygons

For a more sophisticated solution with high polygon models, there are converters on the market, such as Okino's software, which is the industry standard for moving asset data from SOLIDWORKS 3D files and part files to all major 3D or 3D file formats. PolyTrans|CAD imports crack-free geometry (assembly data), hierarchy, and materials from native SOLIDWORKS disk files or from a running copy of SOLIDWORKS. It then intelligently optimizes and converts the data into all major 3D file formats, animation packages, military VisSim, virtual reality (VR) and augmented reality (AR) systems (such as Unity and Unreal Engine), and third-party/OEM integrations. [7]

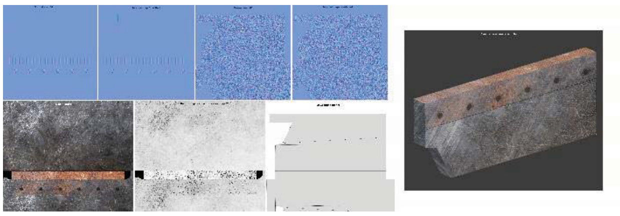

Figure 6. Selected textures for the 3D model

Since 3D content, whether interactive or not, has an exponential trend, we can assume the gradual implementation and expansion of tools in other software for creating and managing 3D content.

Fig. 8 shows a modified model in Unity with an added interaction, which in our model represents turning off/on the device remotely, displaying text fields with information about the device, and starting the knife cutting animation. The image was taken with the camera built into the Hololens in a real environment while adjusting the positioning of the model.

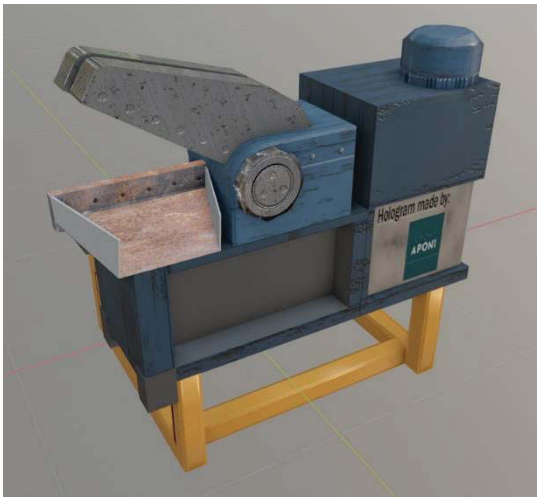

Figure 7. 3D model with textures

C. *Creating your own hologram*

The possibilities for creating your own model consist of two basic choices.

The first is the import of a 3D model from a CAD system, database, or program for the creation of 3D content with the option of exporting data in the preferred formats of the chosen engine, such as Unity.

The second is to create your own model from the scratch. If you have a graphic background ready for application development in Unity, you can use C#. To work with JSON data, you can use JSON Utility which is part of Unity Engine. JSON Serialize Module [9]

AR Foundation allows you to work with augmented reality platforms in a multi-platform way within Unity. This package presents an interface for Unity developers to use but doesn't implement any AR features itself. To use AR Foundation on a target device, you also need separate packages for the target platforms officially supported by Unity:

- ARCore XR Plugin on Android,
- ARKit XR Plugin on iOS,
- Magic Leap XR Plugin on Magic Leap,
- Windows XR Plugin on HoloLens.

D. *Hololens*

Our chosen device HoloLens 1 from Microsoft was used for a real demonstration of interactivity using gestures. The real-size model was launched using fiducials in the form of a square-shaped logo that was easy to scan. Loading the logo launched an application built using the Unity engine and anchored in space.

Microsoft HoloLens is a mobile, head-worn augmented reality device that is wireless and can map its immediate environment in real time as triangle networks and simultaneously locate itself within those three-dimensional networks. It represents one of the most preferred indoor output HMDs for ARIT. The device is equipped with various sensors, including four surveillance cameras and a time-of-flight (ToF) camera. The user has access to sensor images and their positions estimated by the built-in tracking system. [20]

The accuracy of the location of the resulting interactive object - hologram is a decisive aspect in the quality of the mediated experience. [11] Our depicted object in life size was anchored in space. Once the hologram is locked and placed in the real world, it should stay where it is placed relative to the surrounding environment as shown in Fig. 8 and independent of user movement or small and infrequent changes in the environment by utilizing the HoloLens HMD.

Figure 8. A model of the device in a real environment captured by the Hololens

Frame rate is the first pillar of hologram stability. For holograms to appear stable in the world, each image presented to the user must have the holograms drawn in the correct spot. The displays on HoloLens refresh 240 times a second, showing four separate color fields for each newly rendered image, resulting in a user experience of 60 FPS (frames per second). To provide the best experience possible, application developers must maintain 60 FPS, which translates to consistently providing a new image to the operating system every 16 milliseconds. [11] frame rate consistency is as important as a high frames-per-second.

Figure 9. A model of the device in a real environment captured by Hololens in an industrial environment

The human visual system integrates multiple distance-dependent signals when it fixes and focuses on an object. [11] The issue of optics is an advanced science and is different for each device, depending on the chosen technology. The basic principles are divided into 3 categories in relation to the human eye:

- Accommodation - Focus of the individual eye.
- Convergence - Two eyes moving in or out to center on an object.

- Binocular vision - Differences between left and right eye images that depend on the distance of the object from your fixation point.
- Shading [11]

The HoloLens device, which was used in the creation of the demonstration and the starting device, uses an optical distance of 2 meters, as the HoloLens are fixed at its optical distance from the user.

App developers control where users' eyes converge by placing content and holograms at different depths. As users adjust and zoom in at different distances, the natural connection between the two stimuli is broken, which can lead to visual discomfort or fatigue, especially if the scale of the conflict is large. [11]

HoloLens has a sophisticated hardware-assisted holographic stabilization technique known as reprojection which is divided into 4 modes*: Depth Reprojection, Planar Reprojection: Automatic planar reprojection and none reprojection*

In Unity, Depth Reprojection is done using the Shared Depth Buffer option in the Windows Mixed Reality Settings pane under Manage XR Plugins. DirectX applications call CommitDirect3D11DepthBuffer. The application should not call Set Focus Point.

a) Testing

For this research, we tried to give the user an easy way to see how you can manage the hologram. Considering it as a test of a well-designed application that the user should use simply and intuitively.

The initial problem arose with the selection of an inappropriate color spectrum. The darker the color, the more transparent it appears, so we had to do color spectrum correction after the first test.

The task faced by the inexperienced user consisted in managing the control panel and examining the functionalities already on the anchored hologram in space. As a result, it was easy to intuitively move around in the application but interacting with hand movements required some time to master a new skill in rotating, enlarging, and relocating holograms. Although our concerns were mainly the fear of an oversized model with an emphasis on the details of the device, the user overlooked the minor flaws and left excited.

IV. EXTENDED OPTIONS FOR UAVs

The usability of this technology and approach can also be applied in the case of UAVs. The source of visual data for further processing can be a camera system of a drone that circles the object of interest. Then follows 3D scan of the object, which can be post-processed for AR visualization. As part of the research activities, further attention will be focused on the benefits of UAVs for shape mapping and their transformation into the AR world. These solutions can easily find application in industry. By adding network-secured data collection, it is possible to make remote 3D visualizations of the monitored object in almost real time. [22][23] The work that is now done by manual modeling of distant objects can be replaced by automated collection of visual data from a drone. [24][25] This article showed that AR visualization is getting closer and closer to the needs of real industry. The integration of UAVs results in synergies between these solutions and the automated scanning process of 3D objects in space flown by drones [26] [27].

V. CONCLUSION

Creating content in interactive augmented reality is a time-consuming complex task that requires graphic modeling skills, programming skills, animating skills, and mastering HCI techniques. The task of creating interactive content can be attributed to the necessity of teamwork with a partial division of work into individual parts.

By demonstrating the creation of a life-size model, it was possible to point out the missing knowledge that led to the time-consuming secondary modification of the model by reducing polygons. You may consider that in the initial phase of working with interactive augmented reality it is more appropriate to use graphic software primarily intended for creating applications in augmented reality.

Disregarding critical attitudes towards the device, HoloLens are currently the most acceptable alternative for working with interactive augmented reality indoors from available HMD devices with an integrated computing system.

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