A DEVELOPMENT KIT FOR AUGMENTED REALITY APPLICATIONS IN HEALTHCARE

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Abstract— Due to the continuous advancements in augmented reality (AR) technologies, new possibilities in the healthcare domains arise. The aim of this work is to generate new aspects of usability and interaction, allowing new ideas for various health based applications to develop. Despite the different challenges, successful applications have made it into the hands of patients. Nevertheless, developers tend to depend on different AR frameworks for their applications. This paper presents the concept of creating an AR development kit that is driven by the requirements and specifications based on healthcare needs. The proposed development kit enables a combination between the needed healthcare functionalities along with the standard process of creating AR applications. The ultimate goal is to provide developers with an easy and user-friendly modular framework that allows the immediate and straightforward functionality integration on demand and the enablement to create optimized, portable and efficient healthcare AR applications.

Index Terms— Augmented Reality; Development Kit, Interactive Framework; Microsoft HoloLens; Healthcare; AR Applications Development; AR Framework Design; Therapy Lens

I. INTRODUCTION

Augmented Reality (AR) is defined repeatedly and similarly in literature. It is a technology that augments virtual elements with real ones in a user's environment in order to influence their perception of the world [1–4]. The origin of the definition goes back to the late 90s when Azuma specified three key features for every AR system [5]. First, it allows adding virtual content. Second, interactions have to take place in real-time. And third, a 3D registration of virtual objects within the user real world should be feasible.

AR is often compared with Virtual Reality (VR). VR is mainly characterized by a computer-generated environment that elicits a strong user experience of presence. Meanwhile, AR allows real scene visualization [6].

The main aim of AR is enhancing the user's sensory perception of his environment in real-time. Based on that, Azuma saw potential in different classes of application [5]. Healthcare was one of the domains that got attracted by the rise of AR technologies and its recent revolution in applications and devices. Generally, healthcare is an activity service, which aims at improving and protecting the health of individuals and society [7]. With the recent increase in awareness regarding healthcare programs, more people are demanding the service. Meanwhile, the available resources such as carers, therapists, and facilities are limited [2]. Many patients suffered a decline in availability of healthcare services due to limitations in regional and logistical resources [2]. Therefore, researchers began to seek more innovative application and increase accessibility to healthcare via medical trials employing immersive virtual environments of AR.

AR is proving to be a new useful technique in the healthcare domain and to patients in different treatment setups including rehabilitation. In some cases, it can even yield some advantages over traditional treatments. This is due to the fact that the patients interact with virtual objects which pose no physical threat to their health. Moreover, the therapist has control over the simulation and can effortlessly generate content and repeat the process as required [8].

Despite of the recent increase in involvement of AR in the healthcare domain, few factors appears to discourage and slow the process of adaption and development of more healthcare AR applications. One of these is the criticality and urgency of dealing with the health domain, where strict regulations are enforced when it comes to human lives. In the same sense, the expectations of the user's experience quality that is presented by AR applications are high. This is because AR plays a role in the users' emotional engagement and sense of presence [6]. In addition to these factors, experience showed that implementing and operating an AR system introduced a big challenge, as it continuously requires a dedicated technician [1].

On another level, challenges appear not only after having the application ready, but also during its realization. AR software developers for healthcare

domain rely mostly on a range of Software Development Kits (SDKs) to create their applications. Depending on the required functionality for the intended application, developers need to combine multiple SDKs. A lot of effort is spent on bridging these features together and getting it running on one platform.

AR healthcare applications tend to share common features and duties. Besides the core functionality of visualizing AR content, almost every application needs for example to:

- Collect analytical data during the process.
- Introduce interaction techniques to the patients.
- Allow the therapist to control the process.

Despite of the existence of common functionalities, no single available AR SDK is dedicated to combine and present these features together. Available AR SDKs focus more or less on the core vision part. Other functionality such as data collection, patients' specific user interface (UI) design, remote supervision, etc. are left to the developers to realize every time they start a new application.

This paper presents the concept of an AR development kit that is designed to provide the best practices for structuring AR content including the needed functionality for healthcare related applications. The functionality will be driven by the proposed questions in Section III and by the commonly needed features of different existing health care AR applications. The kit could be used by different software developers for their healthcare AR applications. They will save time and cost by overcoming the effort of combining different development frameworks to implement common features that are repeatedly needed for this kind of application.

The paper is structured as follows. In section II, related work, the history and the current involvement of AR in healthcare domain are presented, along with the motivation behind creating a healthcare specific AR development kit. Section III introduces the process of creating an AR application and the questions critical for health domain specification. Section IV presents a preliminary proposed structure of the kit and explains its components. Section V presents the planned future work and gives an outlook. The paper ends with section VI concluding the presented concept.

II. RELATED WORK

The history of AR dates back to the 60s of the last century. Still, its first appearance as a standalone research field and a new technology in healthcare only occurred in the 90s [9]. Since then, researchers kept looking for tools to create more immersive and complex virtual environments. The first trials for AR healthcare applications were designed for use during the planning and execution of surgeries [1, 4]. The goal was to enhance the perception of real body parts with visualized augmented complex medical data [1, 10]. A couple of years later, the scope of AR applications in health domain was broadened to include neuropsychological assessment and rehabilitation with applications ranging from the treatment of anxiety disorders over posttraumatic stress disorders to eating disorders and obesity [1, 8]. The intention is to help the patient in acquiring different skills including creativity, attention, memory formation and retrieval, planning, concentration, ready-response, hearing and visual perception and motor coordination. For example, AR has proven to be useful in treatment of several psychological problems, including phobias such as fear of flying, agoraphobia or claustrophobia [8, 11].

In order to develop health care AR applications, there have been many attempts to create augmented reality SDKs. A quick online search reveals hundreds of SKDs ranging from professional, well developed and documented one to ones that are rather amateurish. Having an overview over all of them is simply impractical. For example, one can find a comparison of more than 70 SKDs on the "Social Compare" website[1].

In AR SDKs, attention is drawn to two main features; Firstly, their support of different vision-based and sensor-based localization and registration methods. This includes natural feature detection algorithms and marker/marker-less tracking approaches that is vital for the accurate alignment between real and virtual objects. Without accurate localization and registration, the experience is affected severely. A framework's performance and support of real-time processing in this feature are important indications. Secondly, their support of different devices and modelling and game engines. It is practical in many cases to deploy the application to multiple available platforms. At least, switching from one device to another should not require starting the entire development process over.

To illustrate examples of existing popular augmented reality SDKs, OpenCV[2] and Vuforia[3] are featured. OpenCV is mostly presented as a real-time computer vision library, which supports cross-platform development. It supports different functionalities such as 2D and 3D feature extraction, facial recognition, gesture recognition, object identification, image

[1] http://socialcompare.com/en/comparison/augmented-reality-sdks (last accessed on Dec, 12th 2017)
[2] opencv.org
[3] http://www.vuforia.com

segmentation and recognition, stereopsis stereo vision and depth perception, structure from motion (SFM), motion tracking, etc. This made it very suitable for supporting AR application and therefore it often appears as a native library at the core of other AR SDKs.

Vuforia is a more high level SDK specifically designed for AR applications. Its main key features are its abilities for marker tracking and real-time processing. The main advantage is that it provides different build versions, which make it integrable with different platforms and game engines. Still it lacks the support of needed functionality for healthcare applications such as data collection, support for carer or therapist supervision during application execution, etc.

The motivation behind the proposed kit is based on the wide usage of AR in healthcare. Due to the lack of a specific target AR SDK, the suggested kit's functionalities will be driven by the needs of healthcare applications while its structure will include and benefit from the existing native AR SDKs.

III. DEVELOPMENT KIT REQUIREMENTS

In order to create an AR application, a developer carries out few standard steps [4, 13]. The whole process in general complies with the standard software development project. Still, in AR, specific functionalities have to be realized and integrated. The application has to be able to process a camera feed, determining the geometry of the scene and position of recognized objects and markers, projecting the 3D model into the scene, visualizing the composite video frame [13].

A list of steps for creating an AR application is summarized in the following:

- As a first step, the idea has to be formulated and the concept of the intended application has to be specified. It is very vital for the developer to communicate the requirements and specifications with the application owner and end users to facilitate the process of the system design and the decision on what other third party SKDs to use.
- An important step is creating the 3D virtual models. Such task might be also delegated to a graphics and modelling specialist. The developer needs to integrate these models into the perceived reality of the user and enable them to see it.
- A suitable AR-enabled target device has to be found. This depends on two factors. First, the specified requirements for the application and its ability to provide the described functionality. Second, the performance, cost and availability of selected device. Many applications adapt the widely used smartphone. Others adapt HDMs that are more specific to different scenarios. One requirement that has to be met is the ability to process and interact in real-time.
- In some cases, developers create their own AR tracking, localization and registration functionalities while in others they rely on a third party SDK to provide the necessary logic. This is the core of every AR application and the hardest to achieve.
- As a last and continuous step, developers tend to bring the results of the pervious steps together to form a deployable version of the application. This is usually done via a game engine or specialist software to create the suitable builds, for instance Unity3D.

The three middle steps actually form a one to one realization of Azuma's three AR application key features.

Developing an AR application for healthcare specific domains requires more features than just creating models and visualizing them using an AR device. Normally, AR scenarios evolve from existing analoguely designed scenarios of therapy and healthcare. They are target-specific (i.e. patients). They might also involve therapists or carers as well. This brings more requirements and specifications to the developer and enforces different questions on what can be enhanced and developed as a healthcare targeted AR framework, such as:

- What is relevant in AR for healthcare? What functionality comes along with AR in healthcare applications? What components need to be introduced and integrated? How should the modularity of these components be formed and what interfaces should be built?
- Which analogue steps carried out by the carer or therapist can be transferred and integrated into an AR solution? Are there any standard steps for every healthcare, therapy or rehabilitation related process?
- Which AR-enabled devices need to be supported? Should the development kit support builds for different platforms and operating systems?
- What interaction techniques need to be realized (e.g. voice, gesture and/or object recognition, etc.)? What UI elements must be designed and what specifications need to be met?
- What artificial intelligence components can be integrated (e.g. virtual artificial carer)?

The mission of the proposed development kit is to enable and take full advantage of the AR technology, and in addition providing necessary healthcare functionality as well as streamlining the standard process of creating AR applications. The ultimate goal is to provide developers with an easy to use and modular framework that makes it easier and straightforward for them to integrate functionality on demand and enable them to create optimized, affordable, portable and efficient healthcare AR applications.

IV. DEVELOPMENT KIT DESIGN AND STRUCTURE

Introducing a development kit that enables AR technology creation on different devices such as smartphones, HoloLens, etc. for enhancing healthcare systems needs to adapt existing SDKs and create new components. In the following subsections, the adapted target device, target platform and preliminary system's components are discussed.

A. Microsoft HoloLens as a Target Device

Along with developing the AR concepts, hardware devices were also evolving and improved over time. New AR-enabled devices available on the market pose significant potential for new applications. In order to achieve the three key features that Azuma defined for AR applications, every AR device should be able to understand the user's environment as a main core functionality. This enforced the hardware requirement of a vision camera. Using its feed, the device tries to extract feature points from the real image and identify the environment in order to achieve what is called localization [3].

In healthcare, different AR-enabled devices were used. Projection displays as hand-held or Head-Mounted-Devices (HMD) were used first. HMD on one hand is a display system that is worn on the user's head, as would a helmet or glasses. It became widely used and evolved especially through the invention of Oculus VR [12]. Different HMD products appeared on the market presenting a wide range of hardware specifications, stability and cost. Among the commercially available hardware are Samsung Gear VR, HTC Vive, Google cardboard and, most recently, the Microsoft HoloLens, to name a few. On the other hand, beside the usage of robotic arms and gloves as hand-held AR-devices [2], smartphones are widely used for AR applications as well. This is due to the sensors and camera required to run an AR application being a core design feature of most modern smartphones. However, the smartphone-based augmented reality platform has the disadvantage of having to hold it in the hand to view information [3], which in some cases impairs immersiveness, user experience, and freedom of movement.

Adapting one specific device makes it easier to plan different components and implement unified interaction techniques. For the proposed development kit, the Microsoft HoloLens is adapted as the main target device. It is the most recent and innovative AR device on the market as it was presented by Microsoft in early 2016. It is a high quality, standalone and comfortable to wear device. HoloLens is equipped with multiple color and depth cameras along with other necessary sensors. Being developed by Microsoft gave the advantage of a direct and native support of Windows 10. With the development of the HoloLens AR headset, it is expected that this will facilitate the development of a new range of healthcare applications [1].

Even though HoloLens will be the main target, the development kit design will be structured and modulator as to enable its usage on other platforms such as smartphones. Not all interaction techniques and experiences can be transferred, but still it can be a fallback solution in case a HoloLens is not available. The key to this portability is adapting a game engine that can create several builds that suit different platforms.

B. Unity3D Game Engine Support

An AR developer normally adapts the game engines to create their application builds. It provides an easy access to the gaming pipeline where the 3D virtual scenario logic can be integrated with the needed components to be deployed on cross platform targets. The choice of the game engine is usually determined by the target platform, usage complexity, and supported programming languages[4].

The proposed kit provides native Unity support. Recently, Unity has become the primary development platform for AR applications. It provides widespread native support received from many AR vendors. Apparently, Microsoft has made it clear to developers through its tutorials that Unity would be the only way to create applications for HoloLens. Google also provided Unity support when releasing their Cardboard SDK. Other SDKs such as Tango and Intel's RealSense also directly support Unity.

Designing a development kit that is implemented in Unity allows a direct support for different devices builds. The different components will be implemented to adapt the main functionalities for the HoloLens and different compatible versions will be provided for other varieties of devices such as with smartphones (i.e. Android and iOS). Unity is flexible to be configured to generate different builds from different compatible implementation.

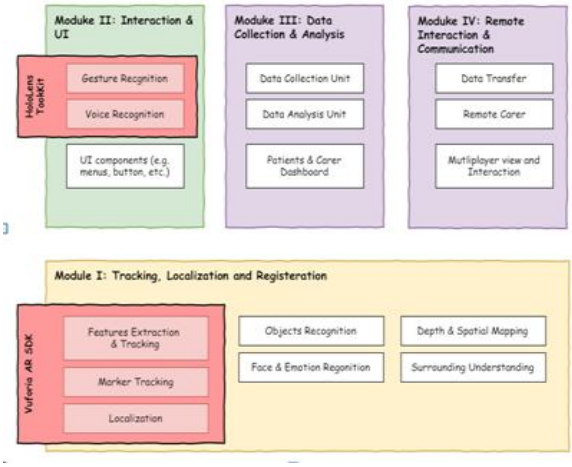
As a result, building an AR SDK that directly supports Unity would yield the greatest interest of most commercial AR developers. One particularly striking advantage is its support of the C# programming language, which is fully compatible with the native Microsoft .Net framework and is supported by the Visual Studio IDE. An easy to use development environment with solid debugging tools and emulators is provided.

[4] A full list is available under: https://en.wikipedia.org/wiki/List_of_game_engines

C. Preliminary System's Components and Structure

The proposed AR development kit is composed of several modules. Each module realizes few connected functionalities, which are commonly needed in AR healthcare applications. Fig. 1 shows the preliminary structure of the proposed kit framework. Some of the functionality will be provided by third party SDKs, which can help advance the development of other components.

Fig. 1 Augmented Reality development kit prelimnary structure



In the following, each module is briefly described:

- Module I: This module holds the core AR functionalities and acts as a base for other modules. Its main functionality is to process the environmental feed from either the cameras or the sensors and establish a better understanding of the users' environment. This will help create an enhanced experience for the user by registering the virtual objects in the right positions and being able to recognize real objects. The localization and marker tracking is adapted from the Vuforia framework. Vuforia provides a stable tracker. In the next steps of the project, developing more stable and reliable object recognition engine will be a priority.
- Module II: This module establishes the main interaction techniques between patient and environment. Users normally interact with the presented content by means of voice or hand gestures. HoloLens Toolkit provides the necessary basic functionality for this. It is still necessary to define a variety of generic gestures, which can be used with patients, especially those with different disabilities. Moreover, user-friendly UI components must be developed, such as menus, buttons, cues, timers, etc. The design should follow specific patients' user-friendliness requirements.
- Module III: During every healthcare process, therapists or carers need to gather data in order to establish an understanding of the patient's behavior and their progress over time. This module builds the basic blocks of data gathering functionality through every step the patients is carrying out. User movement and interaction must be tracked, analyzed, and saved in the process. The data-gathering module saves the collected information in a defined structure. It also provides a user-friendly interface to retrieve the data and the ability to analyze it.
- Module IV: An often-required core feature is remote communication with the patient during use of the application. Healthcare procedures often require the presence of a therapist or carer. Technology can be used to establish a remote interaction between patient and therapist. This concept enhances the home-based care service in general as it minimizes the effort, time, and cost of supporting multiple patients. The module builds the functionality necessary for network communication and live transmission of the user's view to the carer.

The modular design of the kit gives the option of standalone usage of each individual module, as well as a chance for additional development and focus on specific functionalities. In the presented setup, modules are in continuous interaction via defined interfaces. The final output is a unity package that can be imported by different developers. They can easily reuse the defined modules and integrate them with their project. There will be no need for rebuilding basic needed modules such as data gathering or remote interaction.

The proposed SDK usage range can also be extended to other AR application domains. Developers can chose the needed functionalities based on the developed application needs. In spite of that, the SDK is restricted to Unity as a development kit. Although the SDK functionalities can be deployed to different devices, but and many of them are optimized for the HoloLens design and specifications.

V. OUTLOOK & FUTURE WORK

This paper presents the concept of building an AR development kit for application in the context of healthcare. The need arose first during the implementation of a recent project called Therapy Lens. The project started in early 2017 and is funded by the EIT Health of the European Union[5]. The TherapyLens (TL) application aims to capitalize on the recent developments in the field of AR technology to bring a new dimension of support to the field of neurological rehabilitation. Typically, the rehabilitation of activities of daily living (ADL) following a stroke or a neurological disease requires support and monitoring by a family member or a trained professional. The TL application supplements these existing methods of support by providing users with a safe, challenging and interactive AR environment to perform and practice their

[5] http://eithealth.eu/

rehabilitation tasks at home. The presented scenario is supporting the patients in tea preparation as one of their basic ADL (refer to Fig. 2).

The challenge appeared in the lack of existing AR SDKs to establish specified application for healthcare. The proposed development kit aims to support the TherapyLens application and similar applications.

Fig. 2 Tea making scenario using augemnted reality



Fig. 3 First results of TL application development using the proposed kit.

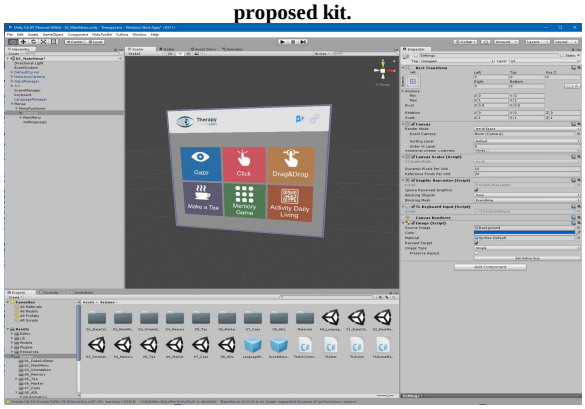


Fig. 3 demonstrates the first results of the Therapy Lens applications. The initial implementation of the development kit is directly used in the TL application. The package hierarchy shows different components already. Based on the development kit the application was built mostly via drag and drop and configurable parameters.

The development of the framework will follow the TherapyLens project timeline where a first beta version is intended for presentation by end 2017. This demo is not a showcase of the entire features set. Some functionality will be developed continuously and provided over time. At this stage, TL application is the first application to proof the usage of the development kit.

VI. SUMMARY & CONCLUSION

AR has been introduced in different domains. In the healthcare area, it displayed several advantages over traditional treatment methods. AR helps overcome the limitations of healthcare access and the huge demand for continuous support. It also provides a safe, harm-free augmented reality environment for the patients to interact with while being monitored by the physicians or other responsible parties. The. AR application developers rely on third party SKDs to build their projects; higher demand started to ascend for a specific SDK that targets healthcare applications, which includes the common recurrent standard features. This paper presents the concept of an interactive AR framework in the context of healthcare and answer main questions that play a critical role in determining and defining the requirements. The proposed framework is presented using a modular approach to enable an easy-to-use supportive development kit.

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