Design of Virtual Reality Browser Platform for Programming of Quantum Computers via VR Headsets

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Design of Virtual Reality Browser Platform for Programming of Quantum Computers via VR Headsets

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Abstract— **Quantum computers are expected to offer an effect similar to the influence of the early integrated circuit computers. According to current systems, it is predicted that they will play an effective role in the emergence of a stronger technology with an increasing speed. Some high-tech companies have quantum computer designs that they actively put into use from the research and development phase to the problem-solving phase and these computers use different architectures. Unlike the others, IBM launched a cloud-based software infrastructure in 2016 and first introduced its 5-qubit quantum computer, which consists of sequential quantum ports architecture, to the use of researchers and interested parties via its web servers. Programming is done by using quantum gates via a web interface called quantum composer. Significant progress has also been made in virtual reality technologies and virtual reality based browser platforms have been developed. In this paper, studies on the using and training of the IBM quantum composer platform through a browser designed on the basis of virtual reality are presented.**

Keywords— Quantum computer, quantum composer, quantum circuit, cloud based software, virtual reality browsers

I. INTRODUCTION

In our study, which includes the use of two different disciplines together, these disciplines were examined separately. The findings obtained as a result of a wide literature research show that, since the end of 90s and start of 2000s, there are numerous academic research and application conducted on virtual and augmented reality. In addition, academic studies on virtual reality (VR) and augmented reality (AR) are compiled, published and conferences are organized by a number of institutes that are experts in their fields.

Virtual reality studies emerge as a branch of human interface studies. These studies are also published in IEEE / CVF International Conference on Computer Vision magazine, which is in the list of first 100 journals according to Google Scholar Metrics. IEEE organizes virtual reality conferences almost every year since 1993 and the studies are shared at http://ieeevr.org/.

The HCI (Human Computer Interaction) international conference, which was established in 1984, organized a separate conference on virtual reality with the title of "1st International Conference on Virtual Reality" in 2005. These studies were published in the second "International Conference on Virtual Reality" held in 2007 and all published articles on VR started to be collected under a single book. The first two conferences were organized under the title of VR, then the 3rd and 4th conferences were organized under the title of VMR (Virtual and Mixed Reality). It has been continued with the name of VAMR (Virtual-Augmented and Mixed Reality) since the 5th conference. Information about these studies organized by HCI can be accessed at http://www.hci.international/.

Virtual reality conferences have been organized by the association of "International Association of Computer Science and Information Technology" as "International Conference on Virtual Reality" since 2015. Information on conferences organized so far can be found at http://www.icvr.org/.

First VR applications in education are seen in 90s. It is used effectively in the education of subjects that are invisible and difficult to embody. Immersion and interactivity relation is shown in detail by virtual chemistry application (1). The success outputs obtained as a result of the reinforcement of molecular chemistry topics, which is difficult to conceptualize, with 3D models is also a good example (2). In (3), it is seen that a successful vision had been drawn about the future applications of VR/AR and today these have been mostly realized. A more detailed survey on blending of virtuality and reality in terms of the focus and contrast of the display equipments are presented in (4).

VR/AR applications have also good experimental results in authentic learning (5). Measurement of critical thinking (CT) in specific science domains such as physics has a crucial importance and researchers also need to have valid and reliable tests to evaluate the effectiveness of such instructional efforts (6).

VR/AR applications emerge as an independent sub-discipline of human interface studies, it is used in a wide range from defense industry (7) to entertainment sector (8), from health education (9) to vocational education (10, 11) and even kindergarten education (12) from industry 4.0 production management and planning (13) to safety of autonomous vehicle technologies (14) and simulation of transportation vehicles (15). In shortly, studies on this discipline continues by increasing effect with each passing year.

This potential that virtual reality has will enable it to emerge with different applications every day. In this paper, the outcomes of a study made within the scope of a novel application of virtual reality are explained. A training environment called QU-VR was prepared in VR environment for programming of quantum computers.

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II. Related Works

A. Brief Info on Quantum Theory and Programming

Quantum theory and design of computers that have the principles of quantum mechanics has a long history. The principle of simulating nature (16,17) and the speed limit of classical computer technologies working with deterministic logic (18) have led researchers to studies on this subject.

Today, production and development of quantum computers are carried out both on a scientific and commercial basis by various institutions such as IBM, D-wave technology and Bell laboratories. IBM has developed a web-based composer that can be used via cloud technology in order to program quantum computers by researchers with remote access.

Generally, discretization technique is used to visualize time or random situations with existing computers. This algorithm makes it impossible to visualize quantum mechanics with classical computers (16). Computation is generally classified into four categories as shown in Fig.1 and quantum computers make quantum computation possible. Other three ways are referred as "classical" computation (21). Quantum computing also has subcategories, and this study is based on IBM's architecture using the quantum gates model. There is also D-Wave 2000Q quantum computer using the *adiabatic* model (21, 22), which can be programmed over the Internet through a platform called Leap-2.

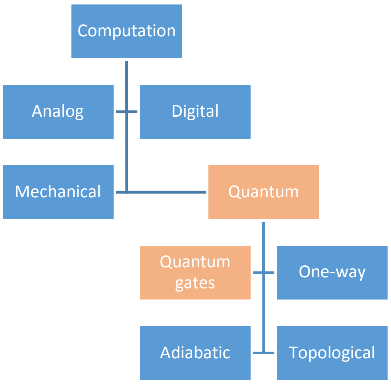

Fig. 1. Computation tree (21)

In this paper, we prefered IBM's publicly available quantum computers and we mostly used the ibmqx4 backend, which is a 5-qubit computer, although other quantum processors and backends freely accessible through the IBM Quantum Experience platform (20). These processors can be accessed by visiting the IBM Quantum Experience website (https://quantum-computing.ibm.com/).

Each qubit is on a different frequency with a principle similar to the musical note and the operating frequencies are determined by the designers of the system (for the IBM Q 5 Tenerife station; Q0 = 5.25 GHz, Q1 = 5.30 GHz, Q2 = 5.35 GHz, Q3 = 5.43 GHz and Q4 = 5.18 GHz).

Quantum gates used by ibm quantum composer platform are listed in Table 1 by 2020.

Table 1. Quantum Gates

Quantum gates	Composer reference	Operator Name or Short Description
H gate	H	Hadamard
CX gate	⊕	Controlled-X
Id gate	ID	Identity
Rx gate	Rx	Rotation over X
Ry gate	Ry	Rotation over Y
Rz gate	Rz	Rotation over Z
X gate	X	Pauli-X
Y gate	Y	Pauli-Y
Z gate	Z	Pauli-Z
S gate	S	Phase (Rotation over Z with $\pi/2$)
Sdg gate	$S^{\dagger}$	Inverse Phase (Rotation over Z with $-\pi/2$)
T gate	T	Rotation over Z with $\pi/4$
Tdg gate	$T^{\dagger}$	Rotation over Z with $-\pi/4$
cH gate	cH	Controlled-Hadamard
cZ gate		Controlled-Z
cRz gate	cRz	Controlled-Rz
ccX gate	⊕	Toffoli
SWAP gate		SWAP

(https://quantum-computing.ibm.com/docs/circ-comp/q-gates)

A sample application designed with IBM quantum composer gates is shown in Fig. 2.  is a measurement tool used to get a qubit's computational value. Possibility distributions of computational values are send to user in the form of histogram table as shown in Fig. 3.

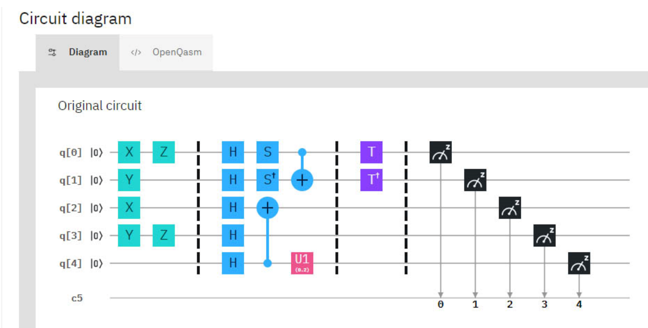

Fig. 2. A sample application

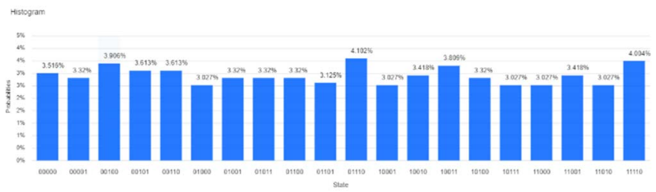

Fig. 3. Histogram table of possibility distrubitions of qubits

Computational results are shown as histogram. In principle, the working mentality of this process is as shown in Fig. 4. The purpose of this study is not how the quantum composer works and how to interpret the histogram results related to qubit outputs. Therefore, these issues will not be explained in detail and mostly the training portal to be created with VR equipment will be mentioned.

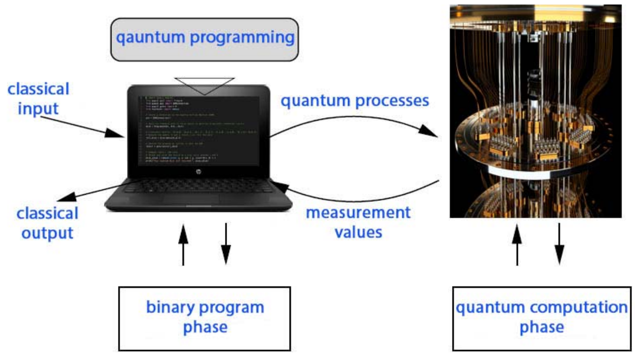

Fig. 4. Quantum programming process

B. *Brief Info on Unity3D Platform*

Unity3D is a popular 3D game design program supporting also 2D design and a developed C# based scripting language (23). Although this platform is launched as a platform for 2D or 3D game design, it has a structure that offers a good educational platform design with its powerful tools (24).

This paper focuses on the use of Unity's 3D design studio for VR applications and the realization of the targeted training platform in this way. Thus, it is desired to make quantum programming remarkable and entertaining with the use of today's modern educational tools.

III. QU-VR TOOL

There are some commercial VR browser applications, such as Vuplex VR/AR Browser (Fig. 6) and Firefox Reality Browser (Fig. 7). Vuplex VR/AR provides to user some developed tools and 3D user controlled web browser API. It allows to user send messages from C# to JavaScript and vice versa. This provides an interactive control of web pages and using the web pages in any VR application. This browser comes with an on-screen keyboard. However, these features and add-ons require a license purchase.

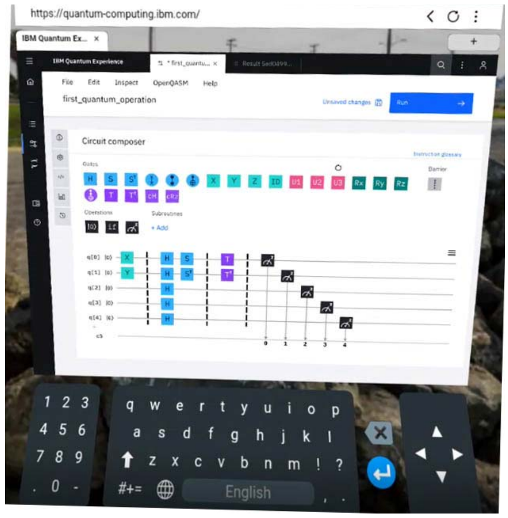

Fig. 5. Vuprex VR/AR view

It is possible place a prefab in your scene that you can click and scroll.

Mozilla FirefoxVR also provides a developed and extremely flexible user friend interface but this is not an open-source platform.

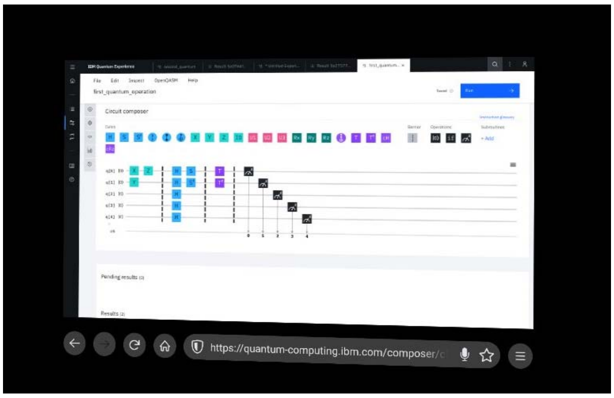

Fig. 6. Firefox Reality view

Mozilla team introduced for self designers a free browser API fully functioning Android plugin based on the GeckoView browser engine and works on the Oculus Go. Controller and keyboard control were not available in the first project version. Oculus Go controller and a free keyboard support have been embedded externally.

In our study, some remarkable images for QU-VR platform were licenced by creating Adobe Cloud and Adobe-Stock account. These images are listed in Fig. 7. A screenshot from QU-VR tool is seen in Fig .8.

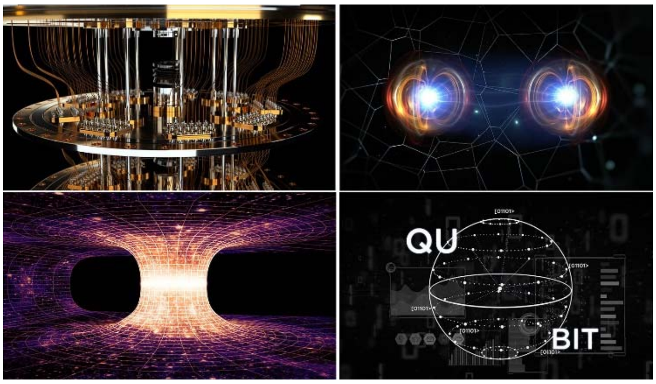

Fig. 7. Images used for 3D VR platform

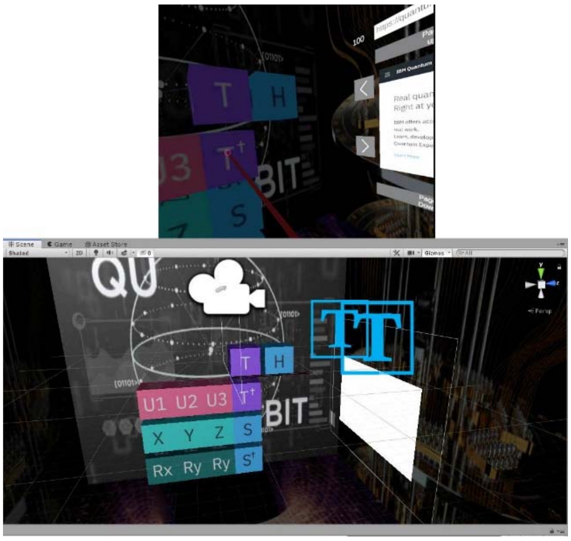

Fig. 8. 3D views from free QU-VR platform and Unity workshop

This browser engine relies on the OVROverlay from Oculus to render frames generated in an Android plugin onto a Unity3D texture. It uses a Java plugin that renders an Android WebView to a Bitmap by overriding the view's Draw method, converts that to a png and passes it to a unity RawImage.

The requirements are

.../Assets/Oculus,

.../Assets/Plugin/Android as folders and

.../Scripts/BrowserView.cs,

.../Scripts/UnityThread.cs as scripts.

After a bit of configuration is made for the BrowserView.cs to work properly, these scripts are sent to convert and Android WebView to a texture that Unity's RawImage can display as shown in Table 2.

TABLE 2. THE WEBVIEW'S DRAW METHOD TO CREATE THE BITMAP AND PNG (ANDROID STUDIO JAVA CODE).

```
public class BitmapWebView extends WebView{
    private void init(){
        stream = new ByteArrayOutputStream();
        array = new ReadData(new byte[]{});
        bm = Bitmap.createBitmap(outputWindowWidth,
             outputWindowHeight, Bitmap.Config.ARGB_8888);
        bmCanvas = new Canvas(bm);
   }
    @Override
    public void draw( Canvas ){
        // draw onto a new canvas
        super.draw(bmCanvas);
        bm.compress(Bitmap.CompressFormat.PNG, 100, stream);
        array.Buffer = stream.toByteArray();
        UnityBitmapCallback.onFrameUpdate(array,
            bm.getWidth(),
            bm.getHeight(),
            canGoBack,
            canGoForward );
        stream.reset();
    }
}
public class ReadData {
    public byte[] Buffer;
    public ReadData(byte[] buffer) {
        Buffer=buffer;
    }
}
```

(https://stackoverflow.com/questions/53508682/web-browser-in-oculus-go-vr-application-built-with-unity)

Then the png files is passed to a unity RawImage. In Table 3, Unity receiving side (C# code) is seen.

TABLE 3. WEB VIEW FROM RAW IMAGE, UNITY SIDE CODE.

```
// class used for the callback with the texture
class AndroidBitmapPluginCallback : AndroidJavaProxy
{
    public AndroidBitmapPluginCallback() :
base("com.unityexport.ian.unitylibrary.PluginInterfaceBitmap
") { }
    public BrowserView BrowserView;

    public void onFrameUpdate(AndroidJavaObject jo, int
width, int height, bool canGoBack, bool canGoForward)
        {
        AndroidJavaObject bufferObject =
jo.Get<AndroidJavaObject>("Buffer");
        byte[] bytes =
AndroidJNIHelper.ConvertFromJNIArray<byte[]>(bufferObject.Ge
tRawObject());
        if (bytes == null)
            return;
        if (BrowserView != null)
        {
            UnityThread.executeInUpdate(()=>
BrowserView.SetTexture(bytes,width,height,canGoBack,canGoFor
ward));
        }
        else
            Debug.Log("TestAndroidPlugin is not set");
    }
 }

public class BrowserView : MonoBehaviour {
// Browser view needs a RawImage component to display
webpages
   void Start () {
        _imageTexture2D = new Texture2D(Screen.width,
Screen.height, TextureFormat.ARGB32, false);
        _rawImage = gameObject.GetComponent<RawImage>();
        _rawImage.texture = _imageTexture2D;

        #if !UNITY_EDITOR && UNITY_ANDROID
        // Get your Java class and create a new instance
        var tempAjc = new
AndroidJavaClass("YOUR_LIBRARY.YOUR_CLASS")
        _ajc =
tempAjc.CallStatic<AndroidJavaObject>("CreateInstance");
        // send the callback object to java to get frame
updates
        AndroidBitmapPluginCallback androidPluginCallback =
new AndroidBitmapPluginCallback {BrowserView = this};
        _ajc.Call("SetUnityBitmapCallback",
androidPluginCallback);
        #endif

    }
   // Android callback to change our browser view texture
    public void SetTexture( byte[] bytes, int width, int
height, bool canGoBack, bool canGoForward)
    {
        if (width != _imageTexture2D.width || height !=
_imageTexture2D.height)
```

```
            _imageTexture2D = new Texture2D(width, height,
TextureFormat.ARGB32, false);

        _imageTexture2D.LoadImage(bytes);
        _imageTexture2D.Apply();
        _rawImage.texture = _imageTexture2D;
    }
}
```

(https://stackoverflow.com/questions/53508682/web-browser-in-oculus-go-vr-application-built-with-unity)

After configurations of these scripts and scenes, all quantum gates were generated and these gate models were embedded into QU-VR platform. Each gate model is used to give user a detailed info about its function.

This tool can also be modified according to the controllers of other VR headsets. Necessary adjustments can be made with the OVRInput API of Unity after adding the assets plugins of the related headset. This app is designed with reference to Oculus Go's only one controller (left or right).

IV. CONCLUSION

In this paper we presented the features of the tool called QU-VR. This tool allows the user to surf in the IBM quantum web composer by Oculus VR headset. It also allows the user to access the help tool about quantum gates very flexibly. This tool is expected to facilitate and make it enjoyable to program quantum computers.

By using the advantage of the 3D design environment, the education portal can be used in all directions. This tool can be modified to any training material to be taught through the VR web browser.

REFERENCES

[1] C. Byrne, "The Use of Virtual Reality as an Educational Tool", PhD thesis, University of Washington, 1996.

[2] L. Farias, R. Dantas and A. Burlamaqui, "Educ-AR: A tool for assist the creation of augmented reality content for education", *2011 IEEE International Conference on Virtual Environments, Human-Computer Interfaces and Measurement Systems Proceedings*, Ottawa, ON, 2011, pp. 1-5, doi: 10.1109/VECIMS.2011.6053850.

[3] R. T. Azuma, "A survey of augmented reality", *Presence: Teleoperators and Virtual Environments*, vol. 6, pp. 355–385, 1997. https://doi.org/10.1162/pres.1997.6.4.355.

[4] R. T. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier and B. MacIntyre, "Recent Advances in Augmented Reality", *Computer Graphics and Applications, IEEE*, vol. 21, pp. 34-47, 2001. doi:10.1109/38.963459

[5] X. Wei, Xiaodong, D. Guo and D.Weng, "Improving Authentic Learning by AR-Based Simulator", *13th Conference on Image and Graphics Technologies and Applications (IGTA 2018)*, Beijing, China, 2018. doi: 10.1007/978-981-13-1702-6_13.

[6] D.T. Tiruneh, M. De Cock, A.G. Weldeslassie, et al., "Measuring Critical Thinking in Physics: Development and Validation of a Critical Thinking Test in Electricity and Magnetism", *Int J of Sci and Math Educ*, vol. 15, pp. 663–682, 2017. https://doi.org/10.1007/s10763-016-9723-0.

[7] G. Fragomeni, S.J. Lackey, R. Champney, J.N. Salcedo and S. Serge, "Training Effectiveness Evaluation: Call for Fire Trainer – Augmented Virtuality (CFFT-AV)", *International Conference on Virtual, Augmented and Mixed Reality (VAMR 2015)*, pp. 263-272. doi:10.1007/978-3-319-21067-4_27.

[8] M. Thöner and A.Kuiper, "Delta Global Illumination for Mixed Reality", *International Conference on Virtual, Augmented and Mixed Reality (VAMR 2015)*, pp. 108-118. https://doi.org/10.1007/978-3-319-21067-4_13.

[9] A. Andrews, "Serious Games for Psychological Health Education", *International Conference on Virtual and Mixed Reality (VMR 2011)*, pp. 3-10. https://doi.org/10.1007/978-3-642-22024-1_1.

[10] R. Lindgren, et al., "Enhancing learning and engagement through embodied interaction within a mixed reality simulation", *Computer Applications in Engineering Education*, pp. 174–187, 2016. https://doi.org/10.1016/j.compedu.2016.01.001.

[11] F.R. Aviles, C.A. Cruz, "Handheld augmented reality system for resistive electric circuits understanding for undergraduate students", *Computer Applications in Engineering Education*, vol. 26, pp. 602-616, 2018. https://doi.org/10.1002/cae.21912.

[12] P. Campos and S. Pessanha, "Designing Augmented Reality Tangible Interfaces for Kindergarten Children", *International Conference on Virtual and Mixed Reality (VMR 2011)*, pp. 12-19. https://doi.org/10.1007/978-3-642-22021-0_2.

[13] D. Ma, J. Gausemeier, X. Fan and M. Grafe, "Virtual Reality & Augmented Reality in Industry", *The 2nd Sino-German Workshop*, 2011. https://doi.org/10.1007/978-3-642-17376-9.

[14] A. M. Nascimento, et al., "The Role of Virtual Reality in Autonomous Vehicles' Safety", *2019 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR)*, 2019, pp. 50-57. doi: 10.1109/AIVR46125.2019.00017.

[15] Y. Wu, Y. Zhang, J. Shen and T. Peng, "The Virtual Reality Applied in Construction Machinery Industry", *International Conference on Virtual, Augmented and Mixed Reality (VAMR 2013)*, pp. 340-349. https://doi.org/10.1007/978-3-642-39420-1_36.

[16] R. P. Feynman, "Simulating Physics with Computers", *International Journal of Theoretical Physics*, vol. 21, no. 6/7, pp. 467-488, 1982.

[17] R. P. Feynmans, "Quantum Mechanical Computers", Foundations of Physics, vol. 16, no. 6, pp. 507-531, 1986.

[18] Y. Kanamori, S.-M. Yoo, W.D. Pan and F.T. Sheldon, "A SHORT SURVEY ON QUANTUM COMPUTERS", *International Journal of Computers and Applications*, vol. 28, pp. 228-233. doi: 10.2316/Journal.202.2006.3.202-1700, 2006.

[19] B. Ömer, "Structured Quantum Programming", *Institute for Theoretical Physics Vienna University of Technology*, 2009.

[20] J. Abhijith, et al., " Quantum Algorithm Implementations for Beginners", arXiv:1804.03719 [cs.ET], April 2018.

[21] D. Padilha, "Solving NP-Hard Problems on an Adiabatic Quantum Computer", B*achelor of Aerospace Engineering Thesis of School of Mechanical and Manufacturing Engineering UNSW Sydney*, 2014.

[22] D. Ciocîrlan, "On the Adiabatic Model of Quantum Computation", *Bachelor of Computer Science and Engineering Department Thesis of Faculty of Automatic Control and Computers University POLITEHNICA of Bucharest*, 2014.

[23] H. Ferrone, "Learning C# by Developing Games with Unity 2019", *Published by Packt Publishing Ltd.*, Birmingham, 2019. ISBN 978-1-78953-205-0.

[24] J.Linowes, "Unity Virtual Reality Projects", *Published by Packt Publishing Ltd.*, Birmingham, 2015. ISBN 978-1-78398-855-6