How Virtual Reality Meets the Industrial IoT

Alberto Vaccari
Aalto University, School of Science
Helsinki, Finland

***Abstract*—The increasing level of virtualization in our world is pushing us to get more and more devices connected to the internet. The same is happening in our cities where data, such as road information, air quality and traffic control, is being gathered and virtualized. This paper gives an overview of the concepts of Virtual Reality, (Industrial) Internet of Things and how they can be interconnected to create Virtual Smart Cities.**

***Index Terms*—VR, IoT, IIoT, HIoT, Smart Cities**

I. Introduction

We live in a time where the distance between Virtual Reality (VR) and our world keeps diminishing. We can see that from the use of the Internet of Things (IoT), both in homes and factories, where everyday objects are connected to the Internet to expand their use and enhance their features. This enables data from these network-connected devices to be transferred around the world, transformed into other types of information and included in virtual simulations.

Starting from the definition of Virtual Reality by Steve Bryson, a pioneer in VR applications at NASA: "[VR] is the use of computer technology to create the effect of an interactive three-dimensional world in which the objects have a sense of spatial presence" [1], it is possible to note that a requirement of VR is to feel immersed in a 3D environment. This *illusion* of immersion is usually created through Head-Mounted Displays (HMD's) worn by the users, but other methods are available [2]. Nowadays, more and more HMD's, such as the Oculus Rift and the HTC Vive, are being developed to make this technology more widely available. This is not a new concept however, as since as far back as 1986, a prototype for an HMD was proposed, which was not too dissimilar from the current models. [3]

Also the idea of using Virtual Reality (or virtual environment, as academics of the time called it) not only on its own (e.g. creating virtual worlds for educational or recreational activities) but also to connect to the outside world is not new [4]. To control an outside agent (i.e. a robot) remotely allows a user to access unsafe locations or perform complex tasks, which requires network-connected systems, devices and sensors [5]. Sometimes, VR can also be directly integrated with the real world to enhance the experience rather than to create an immersive environment. This technology, known as Augmented Reality (AR), has goals similar to VR: it can be used for recreational or educational purposes, or to support difficult tasks, such as the maintenance of complex systems [6] [7] [8].

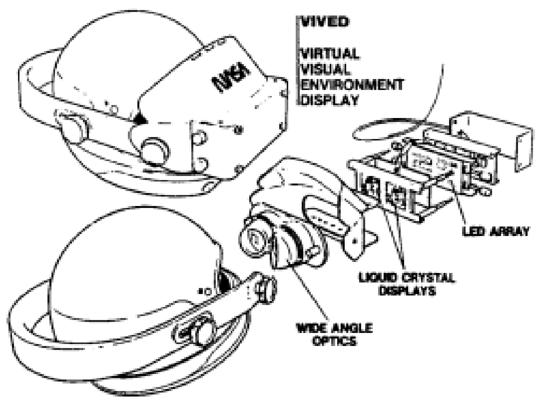

Fig. 1. HMD of Nasa's Virtual Visual Environment Display (VIVED) project.

The rest of the paper is organized as follows: Section II introduces the concept of VR/AR engines and briefly presents their general architecture, showing some examples of architectures of two 3D VR engines. Section III presents the concept of IoT and then discusses its differentiation into Industrial IoT and Human IoT, including the novel VEoT. Afterwards, the concepts of VR/AR and IoT, presented in the previous sections, are merged to discuss new approaches for Virtual Smart Cities, showing some examples, in Section IV. Finally, the paper ends with the conclusions in Section V.

II. VR/AR Engines

A 3D virtual world, which is core to both VR and AR, needs to be created, modelled and handled, and this is done through a specific system, called an engine.
Knowing that VR is the creation of virtual (non-real) worlds using computer graphics, it is not too difficult to see the close link with video games. VR is a video game where the player *is* the protagonist, rather than merely controlling it.
Because of these similarities, 3D game engines are widely used in VR/AR projects [9] [10] [11] [12].

The ever-increasing popularity of video games explains the wide variety of game engines available to developers: from the currently popular Unity3D [13] and Unreal Engine [14], the now-less used Torque 3D [15], Ogre3D [16] and SCUMM (2D engine), to the research-based VeE [17] and VaiR [18]. All these game engines, varying in target devices, supported languages and architectural styles (e.g. OOP, ECS, etc...) share common features.

The basic tasks of an engine is to handle GUI, scenes (the different environments in the virtual world) and their visualization, the connection between objects in a scene (i.e. how the user can interact with other objects,) events, such a collisions and triggers, and execute scripts. Some engines also assist the developers with the handling of networking (connection to external assets or data) and different types of inputs (e.g. keyboards, controllers, HMD's, etc...)

III. IIoT, HIoT and VEoT

Over the years, IoT has rapidly expanded and is still in steady growth [19]. Now that their presence is almost ubiquitous, there is a need to distinguish them according to their category.

As presented in the paper by Moor Insights and Strategy, the IoT can be divided into two main groups: the Industrial IoT (IIoT) and the Human IoT (HIoT) [20].
These two types of IoT still share the same basic architecture but differ in their functional requirements.

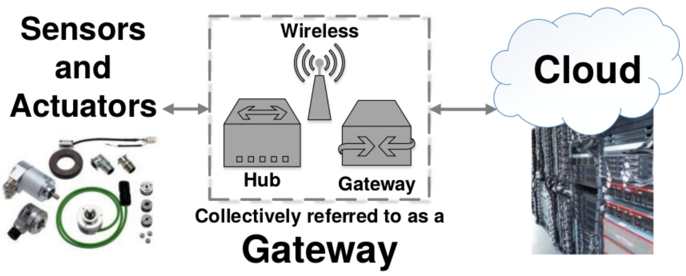

Fig. 2. General architecture of the IoT [20].

A HIoT device can gather data from a house or an office while an IIoT sensor can be found in a factory or a warehouse. It is because of their different uses that their requirements also change.
In the event of failure, a HIoT device has a much smaller impact, as a user would simply replace it, while a similar device in an industrial setting could create significant problems, since it would be part of a bigger automated system. This is why HIoT tends to follow the wants of a user, to improve their lifestyle and well-being, while the IIoT tends to have more reliable (required availability from 0.9999 to 0.99999, compared to 0.99 of HIoT) and long-lasting (until dead or obsolete) devices [20].

In addition to the HIoT and the IIoT, several other categories have been proposed, in order to clearly differentiate the different uses and goals of the vast field that is the IoT.
Given the nature and the topic of this document (Virtual Reality and Internet of Things), one of the many proposed categories, the Virtual Environment of Things (VEoT), has been chosen as a notable mention.

Fig. 3. Architecture of the VEoT [21].

Jih-Wei Wu, at al. in the homonymous paper about the Virtual Environment of Things, presented the concept of "[integrating] real-world smart things and virtual-world avatars/objects in a computer generated virtual environment so that entities in either worlds can interact with one another in a real-time manner" [21]. This brings a new twist to the VR paradigm: a virtual environment which can be modified by external entities (other than the user) and virtual actions which can change the reality we live in.

IV. Virtual Smart Cities

More and more cities all around the world are slowly becoming *smart* in order "to enhance quality and performance of urban services, to reduce costs and resource consumption, and to engage more effectively and actively with its citizens" [22]. This is possible by the growth, among the rest, of the Internet of Things and its increasing accessibility to the public (both in terms of price and usability [23]) that enables more and more data to be collected in cities for analysis and forecasting.

The next step for these smart cities is to be integrated in a virtual environment. This enables not only realistic representation of the past and present state of the city but also forecast of possible future scenario. An example of such a system has already been developed in China, in an academic setup, to use data from a sensor network and connect the virtual and real world [24]. This VR platform for smart cities focused on fire monitoring to simulate the effects of a disaster (i.e. a large fire), in order to give guidance for effectively responding to the emergency.

Another similar project has been developed in Japan, called Tokyo Virtual Living Lab, to integrate street data and traffic information to simulate the traffic situation of the city of Tokyo [25]. It relies on the map data from OpenStreetMap [26] freely available online and the system can be used for simulating a driver and its effects, using a virtual user-controlled vehicle, in a 3D environment.

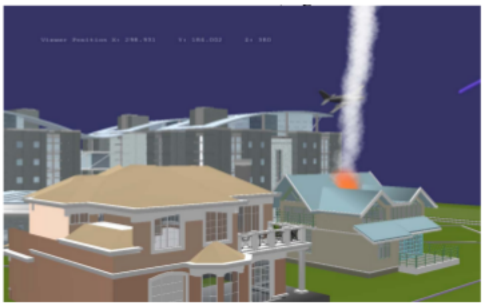

Fig. 4. Fire simulation in the VR platform for smart cities.

Fig. 5. Experimental setup of the Tokyo Virtual Living Lab.

These are two very interesting projects because they show how the real world can be integrated with the virtual one to increase the understanding and giving access to new possibilities, such as disaster simulations and damage containment, very useful in highly populated areas. The architecture behind such a system can seem very complex and new at first. Although it can definitely be considered complex, due to the huge amount of sensors located in a given smart city, its architecture does not highly differ from the one of an online video game, more specifically from the one of a Massively Multiplayer Online game (MMO).

With this in mind, it is fairly easy to see the connection between players of a normal MMO video game, which directly influence their persistent virtual world, and the sensors from a smart city, which similarly influence the state of the virtual environment they are placed in [27].

V. Conclusions

In this document, the topics of VR/AR and IoT have been presented and discussed. Even if seemingly apart, VR/AR and IoT (including HIoT, IIoT and the novel VEoT) are getting closer and closer thanks to developments in both areas and the creations of new (Virtual) Smart Cities.

In the following year, we can expect to see an increasing integration of smart things within virtual simulations, for uses ranging from training, leisure or damage containment.

The vast amount of data being generated by sensors around the world, connected to virtual worlds and simulations, will be the basis of a new understanding of our surroundings (e.g. homes, cities, forests, oceans, etc...) and, perhaps, of the consequences of our actions too.

References

[1] S. Bryson, "Virtual reality: A definition history - a personal essay," p. 4, 1998.

[2] P. Bourke, "idome: Immersive gaming with the unity3d game engine," *Computer Games and Allied Technology 09, Singapore*, 2009.

[3] e. a. S.S. Fisher, M. McGreevy, "Virtual environment display system," *ACM 1986 Workshop on Interactive 3D graphics, October 23-24 Chapel Hill, North Carolina*, p. 2, 1986.

[4] e. a. S.S. Fisher, W. Robinett, "Virtual environment display system," *ACM 1986 Workshop on Interactive 3D graphics, October 23-24 Chapel Hill, North Carolina*, p. 8, 1986.

[5] *From ROS to Unity: leveraging robot and virtual environment middleware for immersive teleoperation*. IEEE, 2014.

[6] e. a. Shen Fangyang, Jia Jun, "Augmented reality aided jet engine assembly and disassembly guidance system," 2010.

[7] M. Fanqi and K. Yunqi, "An improved virtual reality engine for substation simulation," p. 1, 2010.

[8] *Unreal III BASED 3-D VIRTUAL MODELS FOR TRAINING AT NUCLEAR POWER PLANTS*. INREC, 2010.

[9] Z. W. Lin Shi and Z. Li, "Vee: Design and implementation of a generic virtual environment engine," p. 1, 2008.

[10] M. Fanqi and K. Yunqi, "An improved virtual reality engine for substation simulation," pp. 3–4, 2010.

[11] T. Fellmann and M. Kavakli, "Vair: System architecture of a generic virtual reality engine," p. 1, 2005.

[12] *VHD++ Development Framework: Towards Extendible, Component Based VR/AR Simulation Engine Featuring Advanced Virtual Character Technologies*. IEEE, 2003.

[13] Unity3d website. [Online]. Available: unity3d.com

[14] Unreal engine website. [Online]. Available: unrealengine.com

[15] Torque3d website. [Online]. Available: torque3d.org

[16] Ogre3d website. [Online]. Available: ogre3d.org

[17] Z. W. Lin Shi and Z. Li, "Vee: Design and implementation of a generic virtual environment engine," pp. 1–2, 2008.

[18] T. Fellmann and M. Kavakli, "Vair: System architecture of a generic virtual reality engine," p. 2, 2005.

[19] Internet of things companies haul in more than 1 billion in venture capital in 2013. [Online]. Available: cbinsights.com/blog/internet-of-things-investing-snapshot

[20] "Connecting with the industrial internet of things (iiot)," pp. 1–3, 2013.

[21] D.-W. C. Jih-Wei Wu and J.-R. Jiang, "The virtual environment of things (veot): A framework for integrating smart things into networked virtual environments," pp. 1–2, 2014.

[22] Smart city on wikipedia. [Online]. Available: wikipedia.org/wiki/Smart_city

[23] Declining sensor costs open up new consumer applications. [Online]. Available: https://gigaom.com/2015/01/25/declining-sensor-costs-open-up-new-consumer-applications/

[24] e. a. Jie Hu, Wanggen Wan, "Virtual reality platform for smart city based on sensor network and osg engine," *ICALIP2012*, p. 1, 2012.

[25] H. Prendinger and e. a. Kugamoorthy Gajananan, "Tokyo virtual living lab: Designing smart cities based on the 3d internet," *IEEE Internet Computing*, p. 1, 2013.

[26] Openstreetmap website. [Online]. Available: openstreetmap.org

[27] e. a. Nobutaka Matsumoto, Yoshihiro Kawahara, "A scalable and low delay communication scheme for networked virtual environments," p. 1, 2004.