A New Model for Cognitive IVT based on IoT for Critical Safety Solutions: Firefighter Use Case

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Abstract

Immersive visual technologies and Internet of things are considered the main paradigms in defining new models of immersive training for critical safety applications. Accordingly, matching appropriate devices and technologies with the training requirements and its individual, technological, and operational factors is mandatory to achieve the training goals. In this context, we investigate and classify different factors based on immersive technologies, emerging devices, and sensors. Furthermore, we propose a new model for cognitive immersive visual technologies for critical safety solutions. The proposed model is validated in a use case of a fire brigade intervention after an earthquake. The use of this model mitigates heterogeneity conflicts due to the variety of immersive technologies for a specific situation by respecting stakeholders' requirements. This paper helps future researchers, industrial and enterprise stockholders to select adequate immersive visual technologies, devices, and engines for creating further critical safety solutions.

Index Terms: Immersive technologies, training, virtual reality, IoT.

1 Introduction

Nowadays, technology has an impact on almost every object in the world and reaches every application. Thus, computing and immersive technologies grow into the highest potential era of the age. Objects can perform a high level of immersive interaction not only with people but also with smart objects. Hence, Immersive Visual Technologies (IVT) in integrative smart applications appears to change our world and also to create more opportunities. This new paradigm aims at providing internet connectivity between physical, virtual and augmented things anywhere, anytime, and with anything. Immersive technologies and computing capabilities, through sensors and virtual or physical objects, may reduce human intervention. Several cutting-edge IVT technologies can improve the User Experience (UX) even though several challenges may hinder the widespread use of Virtual Reality (VR) and Augmented Reality (AR). Among these, the usability of IVT systems is still under investigation. Another possibility offered by the fusion of IVT and Internet of Things (IoT) technologies is that it gives people the power and responsibility to make quick decisions without physical intervention. IoT and IVT bundle many emerging technologies (e.g., sensors, context-aware computing, immersive and communication technologies, service management, etc.) to build new solutions. This leads to the design of several architecture models in order to find a solution for controlling operative control rooms. Here, we present a Smart Immersive Visual Technologies (SIVT) model that deals with several factors. SIVT enables non-technical and technical users to explore, easily create interactive training, and to choose technologies that fit well their requirements based on individual, technological and operation factors.

The remainder of this paper is organized as follows: Section 2 presents related works and some factors related to immersive technologies that can influence training. In Section 3, after reviewing the existing and new technologies of immersive training systems, we describe the basic concepts of cognitive SIVT that are well suited to the scalability of training requirements. In addition, we highlight the generic SIVT layers and cognitive SIVT based self adaptivity. We apply the proposed SIVT model for firefighter use case in Sections 4 and 5. Finally, concluding remarks are presented in Section 6.

2 Related work

In this section, we define different training based IVT/IoT technologies for safety-critical situations. This can help to classify factors that can affect the training through investigating different IVT/IoT devices, sensors and engines.

2.1 Training based on IVT/IoT technologies

Various training models exhibit similar safety-critical situations in different models and technologies. Thus, we split the existing training systems in two categories. The first category [1] - [10] is based on AR and VR. The second category [11] - [13] uses both IoT and IVT technologies for creating safety training systems.

For the first category, Wang et al. [1] provided an integrated design framework for leveraging current advancements in AR to improve the safety of highway-workers by providing real-time multimodal alerts on-the-spot. Furthermore, this study highlights the interest and commitment of highway employees to both the proposed technology and the suggested user interface. Huang et al. [2] defined a VR system for construction safety training that increases an individual's performance in VR using electro-encephalography and physiological data such as blood pressure and heart rate. The usage of VR is intended to provide high degrees of interactivity and immersion. Liang et al. [3] developed a simulation program for an AR device that casts an image of a human face with facial drooping (a stroke symptom) onto a computerized training mannequin. The nursing students were then placed in a clinical simulation in which, wearing the AR equipment, they assessed a patient-manikin to recognize stroke symptoms and respond appropriately. Xu et al. [4] presented an immersive and interactive multiplayer-based teaching platform that uses VR technology in order to increase employees' awareness of safety hazards on urban building sites. The simulation platform is a training solution that enables repeatable and adaptable operations in a secure environment. Rocha et al. [5] developed a VR application that replicates the usage of AR technology to provide

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access assistance and safety recommendations to electric substation operators/maintainers. Lallai et al. [6] proposed to combine task descriptions with AR technology to the benefit of both learners and instructors during training activities. AR interactions offer the advantage of linking the cybernetic and physical parts of an aircraft cockpit, enabling training in this environment better than software tutoring systems. On the instructor's side, the LeaFT-MixeR system enables systematic covering of planned activities while also monitoring student performance in real-time. Wan et al. [7] used a VR development engine, 3D Max, Unity 3D, Visual Studio, and other development software to complete 3D scenarios building and visualization of the oil depot achieving highly realistic picture effects through HD scriptable render pipeline technology. Tan et al. [8] proposed a virtual simulation system for underground grouting fire prevention and extinguishing, allowing students to experience the procedure firsthand and carry out virtual instruction. This methodology may not only boost students' feeling of practical operating experience but also provide practice safety and endless practicing chances without wasting resources. Koteleva et al. [9] demonstrated how AR technology may be used to determine the effectiveness of an AR system for oil pump maintenance.

For the second category, Chen et al. [10] provided a novel technology-integrated framework for prototyping a proof-of-concept Building Information Modeling (BIM), IoT, and AR/VR system based on the logic of situational awareness. A pilot test is undertaken to assess the framework's functioning in a simulated fire situation. The findings indicate that the data supplied by the system may be used by the firefighting department to rapidly pinpoint the locations of interior fires and that the VR gamification situations can aid trainers in developing situational awareness. Morra et al. [11] presented a novel system architecture for managing passenger evacuation safely within an airport terminal in the event of a large interior fire. Along with pre-assessment of fire hazards, the basic idea is that information from a fast-predictive simulation of the fire evolution immediately following the start of the fire could assist the airport safety management system in making split-second decisions to manage extremely specific fire scenarios. The system is based on the joint use of a fire engineering simulation model, IoT safety and environmental sensors, specialized AR equipment and a remote server capable of exchanging data over Wi-Fi connections and analyzing it on a software platform. Aetic et al [12] proposed an IoT-based VR game for physio-therapeutic patients, in which bodily movements are collected via a wearable ultrasonic sensor temporarily affixed to the patient's different limbs. The data from the sensors is then sent to the game through serial wireless connection. Ying et al. [13] presented a system software that might help any first responder, regardless of their first-aid experience. The system software uses a mix of IoT technologies to call for emergency medical help as well as diagnose the kind of first-aid therapy. Vuforia's AR engine in Unity is then called upon through target detection to show an overlaid visual-aid of a virtual assistant administering first-aid to the victim. To develop the suggested end-to-end system software, the different components are combined utilizing the AI's autonomous control over the AR applications.

2.2 Factors based on immersive technologies

Different factors can affect training based on immersive technologies. We classify these factors into three types (as shown in Table 1). *Individual factors* are: presence, age, emotional experiences, bodily experience, distance, mental rotation, visual disability, and position in the simulator. FOV refers to how much of your eyesight will be covered when wearing the VR headset. The human eye has a field of view of around 180 degrees. Therefore, headset with a field of view of 110 degrees can be considered appropriate. Most headsets utilize AMOLED screens which are considered superior to LCD screens. The AMOLED screen has a higher resolution while there is a downside to using LCD which is dark areas on the screen. LCD screens require a backlight which may result in unclear vision. A high-resolution screen will ensure the image is as crisp as possible. The advantages of having a higher FOV lead to increased levels of immersion, which affect the emotional experiences and bodily experience. Older adults cope with issues as reduced visual field and decreased vision [20]. Proper resolution and screen type of the devices can mitigate these issues. The technological factors rely on optical, display, tracking, software corrective features as well as engines, methods, and hardware. Some training requires to not be placed in a limited area. Thus, the lightweight, compact size, the built-in battery of some portable IVT devices allows to easily move. In addition, tracking sensors can recognize fingers, hands, head, and body movement in the virtual environment. Some training needs to use the fingers, hands, head, and body movements of the trainees in the virtual environment. This is a little more challenging problem since some headsets are not meant to monitor the complete body while others can track the trainees across an entire area. The PSVR uses a camera to capture hand motions, but the trainee is constrained to the cable that connects him to the device. HTC Vive and Oculus Rift use more precise body tracking. Some headsets do not require additional cables or cameras; however, they often do not support extensive body tracking. The *operational factors* are based on conditions imposed by the environment (e.g., fog, optic flow generated by land vehicle, aircraft, daytime, and nighttime), the actions of the individual in the environment (e.g., head movements), duration of the training, task hardness aware or specific situations (e.g., sitting, standing, lengthy AR/VR sessions). One solution to consolidate different factors is to conduct human factors analysis to see how trainees use technologies in various operational condition and to implement their needs in the design and development of the training [19]. Several engines can be used to detect and recognize objects in the augmented environment. This can facilitate some critical situations. For instance, some engines can detect objects in smoke better than the eyes of the user. This also can make a less risky intervention in the training.

3 SIVT MODEL

In this section, we introduce the SIVT paradigm. In the last decade, IoT and IVT gained enormous attention from academic researchers, industrial and enterprise stockholders due to the capabilities of IVT in generating interactive visualization and the IoT advantages.P. Guillemin and P. Friess [17] stated that IoT allows people and things to be connected anytime, anyplace, with anything and anyone, ideally using any path/ network and any service. While IVT integrates virtual, augmented, and mixed content with the physical environment which allows the user to engage naturally with the blended reality. As mentioned above, many technologies are managed by IoT and IVT, therefore, the SIVT architecture model could be considered as an umbrella that supports these technologies and provides a relationship between them.

3.1 Generic SIVT layers

The architecture model of SIVT system can be structured into three layers (as shown in Figure 1). The perception layer: Internet and communication networks allow to perceive, detect objects, gather information, and exchange data with several devices in this layer. Thus, this layer senses the physical objects in operative control rooms and acquires data from cameras, sensors as accelerometer sensors, gyroscope sensors, magnetometer sensors, tracking sensors, motion sensors, camera sensors, and RFID. In the decision-making and processing layer, the data acquired from the perception layer will be ingested into data sets through communication and internet technologies. Thus, this layer is responsible for handling the transparent transmission of data while the knowledge and decision layer aggregates, cleans, and fuses collected data and extract them

Table 1: Matching IVT technologies and their emerging devices per individual, technological and operational factors

				Individual factors			Technological factors		Operational factors	
	IVT software	Device	IVT sensors	FOV	Screen	Resolution	Portability	Tracking	Recognition real objects	Environment
AR / MR	Unity, Unreal Engine, ARKit, ARCore, Vuforia Engine, Kontent by Kentico	Hololens 1	Head Tracking Cameras, Depth & IR Camera	30°	Automatic pupillary distance calibration	1280 x 720 (per eye)	yes	one hand tracking	ARToolKit, EasyAR, Maxst, Wikitude, Vuforia, ARCore,	Virtual object / environment combined with real world
		Hololens 2	Head Tracking Cameras, Depth & IR Camera, Accelerometer, Gyroscope, Magnetometer	52°	Display optimization for 3D eye position	2048 x 1080 (per eye)	yes	2 IR cameras, both hands tracing, gestures, voice, biometric identification	ARToolKit, EasyAR, Maxst, Wikitude, Vuforia, ARCore	
VR	Unity, 3ds Max Design, Maya, Unreal Engine	HTC Vive	Accelerometer, gyroscope	110°	Dual AMOLED	2160×1200 (1080×1200 per eye)	no	6 DOF IR Laser-based 360-degree tracking using “Lighthouse” Base Stations	no	Fully artificial environment
		HTC Vive Pro	SteamVR Tracking, G-sensor, gyroscope, proximity, IPD sensor	110°	Dual AMOLED	2880 x 1600	no	6DOF Room Scale Tracking	no	
		Valve Index	Accelerometer, gyroscope, External Cameras	130°	LCD	2880 x 1600 (1440 x 1600)	no	6DOF Inside Out Tracking with Finger Tracking Controllers	no	
		Oculus Quest / Oculus Quest 2	Accelerometer, gyroscope, Internal Cameras	100°	Fast Twitch LCD / OLED	3664×1920 per eye/ 2560 x 1440	yes	6DOF Inside Out Tracking (wireless)	no	
		Oculus Go	Accelerometer, gyroscope	100°	Fast-Switch WQHD LCD	2560 x 1440	yes	Orientation Tracking	no	
		Oculus Rift	Accelerometer, gyroscope, magnetometer	110°	Dual AMOLED	2160×1200 (1080×1200 per eye)	no	6 DOF Constellation camera optical 360-degree IR LED tracking	no	
		Oculus Rift S	Accelerometer, gyroscope, 5 x Internal Cameras	115°	Fast-switch LCD	2560×1440	no	6DOF Inside Out Tracking	no	
		Samsung Odyssey	Accelerometer, gyroscope, magnetometer	110°	AMOLED	2880 x 1600 (1440 x 1600 per eye)	no	2 x 6 DOF camera	no	
		PSVR	Accelerometer, gyroscope	110°	AMOLED	1920×1080 (960 × 1080 per eye)	no	6 DOF PlayStation Camera optical 360-degree LED tracking	no	

from collected data. This layer integrates immersive technologies for interactive data visualization. Finally, in the service layer, a smart immersive environment is created to receive the information and process content to deliver intelligent and interactive services to different users. The seamless integration between the immersive environment with intelligence leads to the appearance of the cognitive SIVT based on the evolution of immersive, pervasive, and ubiquitous computing.

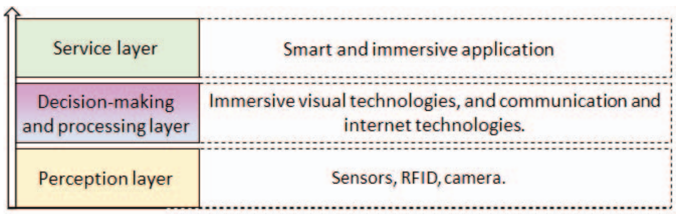

Figure 1: Generic SIVT layers.

3.2 Cognitive SIVT

Cognitive SIVT is the union of cognitive immersive technologies with collected data from headsets and/or controllers of connected immersive devices (as defined in Figure 2). Consequently, the evolution of immersive computing leads to heterogeneous infrastructure challenges. Thus, IVT handles those challenges represented in context-awareness by producing an immersive smart system to achieve user requirements. The objective context addresses the external visualization of service while the subjective context can improve intelligent services to fit some specific Spatio-temporal situations. Therefore, Figure 5 presents cognitive SIVT architecture model. Cognitive SIVT infuses intelligence into the physical world through physical objects and shows the data in immersive environments through VR or AR. Hence, the data produced by IoT sensors are sensed through context management middle-ware. In the decision-making layer, Information visualization and analytics techniques and technologies such as IVT engines are used to provide interactive data. An intelligent and interactive service must ensure the monitoring and control of the proposed system.

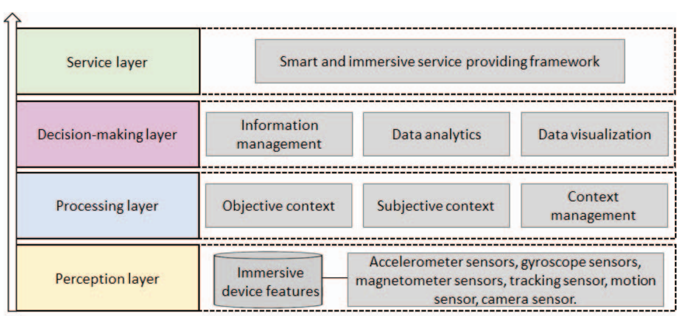

Figure 2: Cognitive SIVT.

3.3 Congnitive SIVT based self adaptivity

Nowadays, self-adaptation has been increasingly important in designing immersive and computing systems. This helps to create training systems with minimal human oversight, which are able to achieve the requirements of business decisions and goals. Accordingly, the *self* prefix means that the system can autonomously reach its goals in training contexts and select the appropriate training system and its related techniques, tools, and technologies without any human intervention. Through self-adaptive, the training system is monitored to collect data related to the training, analyze the collected data in order to decide how to take an adaptive decision, determine steps to achieve a self-adaptive system, carry out the execution of the steps and the changes in the training system. In order to adapt and verify the existing training systems to our proposed system, we define the main tasks in the feedback of SIVT based on self-adaptation (as shown in Figure 3) that is described as follows:

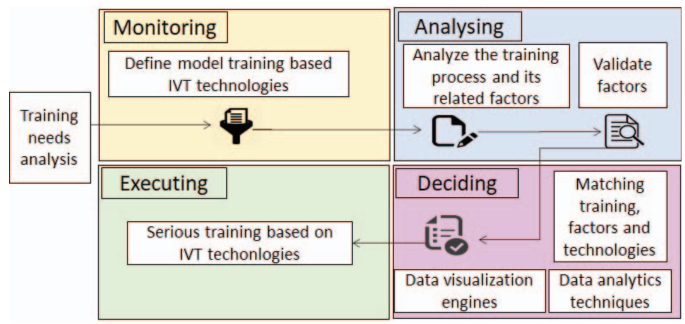

Figure 3: Congnitive SIVT based self adaptivity.

- Monitoring: The collected data from Training Need Analysis (TNA) will be aggregated, correlated, and filtered in order to determine the devices and sensors that are required for monitoring the training.
- Analysing: In this phase, we analyze the training process and its related factors that are provided by the monitoring phase. Knowledge about the different IVT technologies and their individual, technological, and operational factors is necessary.
- Deciding: This phase is about the matching between factors and technologies. The decision-maker is able to modify the choice of technologies and factors that are adapted to the situation's requirements.
- Executing: It structures the actions which are needed to design the serious training based on IVT.

4 Application of SIVT model in the firefighter use case

In this section, we apply and evaluate a simulation-based firefighter training for an earthquake scenario developed in collaboration with national Italian firefighters rescue units [18] on the proposed SIVT model.

4.1 Description

The use case of an earthquake situation was proposed by national firefighters' curators. The intervention is requested following a strong earthquake, which occurred after a previous earthquake that can cause some disruption of the supporting structure of the building, for which provisional shoring works will be carried out. The intervention is necessary following a gas leakage with the consequent development of a principle of fire, developed in the basement, in which there are gas supply pipes related to the heating plant serving the heating system of the building. The basement contains an archive of documents and goods of great historical, cultural value and an inert gas extinguishing system, of which it is necessary to ascertain the conditions of damage and carry out the necessary safety measures. Hence, six tasks have been developed for the game of which one is a tutorial training on VR hardware and other six tasks introduced to perform the task provided by firefighters' curators. The remaining tasks have been designed for the operational procedures of firefighters in an earthquake.

4.2 Training needs analysis for a fire brigade

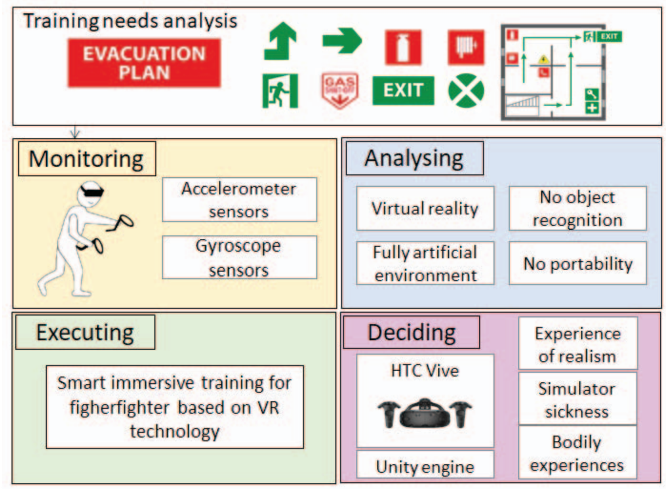

Figure 4: Congnitive SIVT based self adaptivity for firefighters training use case.

In the simulation designed by the fire brigade managers, six tasks were defined to be carried out in a building following an earthquake.

1. The first task is to turn off the electrical power in the basement. The electric panel has several buttons.
2. The second task focuses on turning off the alarm system that was defined by a red box in another area of the building. Thus, the trainee must be aware of the location of the alarm system.
3. In the third task, the trainee must turn off the gas system by turning the heating plant from 100% to 0%.
4. The fourth task is to choose the right fire extinguishers and put them in a cage. In the training, the trainee is able to pick up the appropriate fire extinguishers and perform the task.
5. In the fifth task, the trainee will visualize and read clearly instructions of a gas suppression system that contains pictures and a long text.
6. The last task is to verify the compliance of the wooden structure with the structural requirements in order to check the level of earthquake.

Following the curators' suggestions, these tasks are independent of each other. In the virtual environment, if a trainee fails on a level, the next level is loaded when he presses the next button. This decision can avoid that a trainee is trapped on one level and can easily be an integral part of the game logic.

4.2.1 Monitoring

In the virtual environment the movement of a firefighter is allowed either by teleporting or walking. Thus, a gyroscope sensor is used to allow the movement of firefighters in multi-directions. In addition, an accelerometer sensor measures the rate of change in the movement which leads to a fast system thus reducing the reaction time. Furthermore, the user uses controllers to interact with objects and Head Mounted Display to visualize the simulator environment in the training model.

4.2.2 Analysing

Italian national firefighters' curators proposed a fully artificial environment that defines the use of VR technology instead of AR technology. The simulation runs on a server PC which synchronizes the player to run the simulation. In addition to controlling the direction, controllers are also used to move in the created environment. Hence, teleport mechanics was adopted to enhance the player's movement as well as to control the camera when the player is crouching. When the player is picking up an object, the teleport mechanics will help him to move while performing another task. This gives a better field of view.

4.2.3 Deciding

The base for the simulator environment is the HMD equipment [16]. More specifically, HTC Vive is adopted. The player is surrounded by two tripods that support stations covering the majority of the field of view of the virtual world. As reported in Table 1, HTC Vive pro does not support portability and object recognition. The device allows you to interact with the environment and the immersive sensation, as reported by the subjects, can be very high. Therefore, HTC Vive provides the potential to participants to behave and react almost as reality based on [15]. Additionally, the HTC Vive, as demonstrated in [14], causes less nausea and disorientation effects than other headsets.

4.2.4 Executing

A scenario was simulated in which a group of firefighters enters a basement after an earthquake and performs specific tasks. Before performing the task, the operators must be trained. To train the operators tow modalities have been designed: the normal training model based on paper instructions and the one based on the use of VR (as presented in Figure 5).

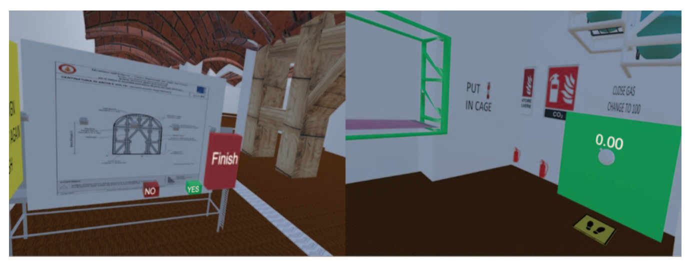

Figure 5: Screenshots of the virtual reality-based system designed for firefighters training [18].

The results of VR training based activities have 78 % of the task completion rate, while the paper training related activities have only 61 % of the task completion rate. Summarizing, we can state that even in the use case of safety critical applications, with people potentially unfamiliar with the use of new technologies, the use of VR improves the effectiveness of training. Furthermore, the duration of VR training is shorter than the duration of Paper training which leads to improving the efficiency of the system (as shown in Figure 6).

4.3 Discussion

Working on critical solutions implies the intervention of several collaborators. Certainly, these contributors exchange knowledge about novel emerging technologies (e.g IoT and IVT) and cognitive information flows. However, it can lead to various representations and interpretations of architecture model for the same critical situation and to select the inadequate technologies, techniques, or devices for the situation. Such failures are described in terms of the first conflicts between technologies which are the results of matching

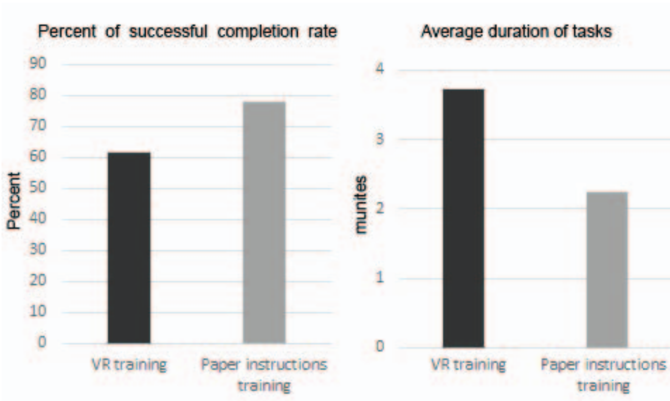

Figure 6: Percent of successful completion rate and duration of tasks per training for effectiveness metric.

inappropriate devices and software used by stakeholders in a critical situation. The second conflicts are related with selecting unsuitable technologies to improve factors. The first conflicts concern the ambiguity that emerges due to the stakeholders' reasoning in the development of the techno-economic solution. Heterogeneities conflicts are due to the diversity of used IVT technologies. The second conflicts are mainly from factors matching problems. Thus, selecting the adequate technology for a specific situation by respecting stakeholders' requirements can solve it. In this context, we can deduce that our proposed SIVT model based on self adaptivity tasks can overcome the problems with these various conflicts and manage the design on serious training based on smart IVT technologies.

5 Conclusions

IVT and IoT play a prominent role in creating immersive training systems. Novel smart and immersive technologies should cooperate to perform complex tasks particularly in creating critical safety training systems, hence the need to design a suitable IVT model based on appropriate technologies. Accordingly, understanding cognitive IVT concepts and investigating emerging IVT devices and sensors provide guidelines for training requirements and its individual, technological and operational factors. In this paper, we have discussed emerging IVT technologies, devices, and sensors. Besides, we have defined basic concepts of cognitive IoT layers and architecture models. Furthermore, we created a new model for cognitive IVT based on IoT to be used in critical safety scenarios. The proposed model, based on self adaptivity, was evaluated in a firefighter-training use case.

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References

[1] Wang, Yuwei, Yimin Wu, Cheng Chen, Bohan Wu, Shu Ma, Duming Wang, Hongting Li, and Zhen Yang. "Inattentional Blindness in Augmented Reality Head-Up Display-Assisted Driving." International Journal of Human–Computer Interaction (2021): 1-14.

[2] Huang, Dongjin, et al. "Virtual reality safety training using deep EEG-net and physiology data." The Visual Computer (2021): 1-13.

[3] Liang, Ci-Jyun, et al. "Enhancing stroke assessment simulation experience in clinical training using augmented reality." Virtual Reality 25.3 (2021): 575-584.

[4] Xu, Zheng, and Nan Zheng. "Incorporating virtual reality technology in safety training solution for construction site of urban cities." Sustainability 13.1 (2021): 243.

[5] Rocha, Victor Menezes, and Saul Delabrida. "Augmented Reality Applied to Reducing Risks in Work Safety in Electric Substations." (2021).

[6] Lallai, Giorgia, et al. "Engineering Task-based Augmented Reality Guidance: Application to the Training of Aircraft Flight Procedures." Interacting with Computers 33.1 (2021): 17-39.

[7] Wan, Jing, et al. "Oil depot safety inspection and emergency training system based on virtual reality technology." IOP Conference Series: Materials Science and Engineering. Vol. 782. No. 4. IOP Publishing, 2020.

[8] Tan, Bo, Liu Yanling, and Wang Kaixuan. "Design and Application of the Virtual Simulation Teaching System for Grouting Fire Prevention and Extinguishment." Proceedings of the 2020 The 2nd World Symposium on Software Engineering. 2020.

[9] Koteleva, Natalia, et al. "Augmented reality system and maintenance of oil pumps." International Journal of Engineering 33.8 (2020): 1620-1628.

[10] Chen, Haosen, Lei Hou, Guomin Kevin Zhang, and Sungkon Moon. "Development of BIM, IoT and AR/VR technologies for fire safety and upskilling." Automation in Construction 125 (2021): 103631.

[11] Morra, Emanuele, Roberto Revetria, Domenica Loredana Scaramozzino, and Gabriele Galli. "A Fire Safety Engineering Simulation Model for Emergency Management in Airport Terminals Equipped with IoT and Augmented Reality Systems." In SoMeT, pp. 303-314. 2020.

[12] AETiC, AETiC, K. Martin Sagayam, Hien Dang, Mohd Helmy Abd Wahab, and Radzi Ambar. "IoT Based Virtual Reality Game for Physiotherapeutic Patients." Annals of Emerging Technologies in Computing (AETiC), Print ISSN (2020): 2516-0281.

[13] Ying, Cheng Zhi. "Development of a First-Aid Smart Assistant Device Using IoT Technology and Augmented Reality." In IRC-SET 2020, pp. 741-757. Springer, Singapore, 2021.

[14] Caserman, Polona, Augusto Garcia-Agundez, Alvar Gámez Zerban, and Stefan Göbel. "Cybersickness in current-generation virtual reality head-mounted displays: systematic review and outlook." Virtual Reality (2021): 1-18.

[15] Saghafian, Mina, Karin Laumann, Ragheeba Sadaf Akhtar, and Martin Rasmussen Skogstad. "The Evaluation of Virtual Reality Fire Extinguisher Training." Frontiers in Psychology 11 (2020).

[16] Melzer, James E. "Design evolution of a wide-field-of-view head-mounted display for aircraft training and simulation." In Helmet-and Head-Mounted Displays VI, vol. 4361, pp. 24-29. International Society for Optics and Photonics, 2001.

[17] Vermesan, Ovidiu, Markus Eisenhauer, Harald Sundmaeker, Patrick Guillemin, Martin Serrano, Elias Z. Tragos, Javier Valiño, Arthur van der Wees, Alex Gluhak, and Roy Bahr. "Internet of things cognitive transformation technology research trends and applications." Cognitive Hyperconnected Digital Transformation: Internet of Things Intelligence Evolution (2017).

[18] Mohamed Saifeddine hadj Sassi, Carli Maro, Federica Battisti. "Simulation-based Virtual Reality Training for Firefighters." In the Image Processing: Algorithms and Systems XX Conference, at IST Electronic Imaging 2022.

[19] Saghafian, Mina, Taufik Akbar Sitompul, Karin Laumann, Kristina Sundnes, and Rikard Lindell. "Application of Human Factors in the Development Process of Immersive Visual Technologies: Challenges and Future Improvements." Frontiers in psychology 12 (2021).

[20] Owsley, Cynthia. "Aging and vision." Vision research 51, no. 13 (2011): 1610-1622.