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(Article begins on next page)

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A Metaverse Between Technical and Humanistic Domains to Reach Society 5.0

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***Abstract* — The metaverse has been recognized as being the next generation of internet allowing immersive digital spaces accessible through multiple devices for different activities. The aim of this study was to investigate the impact of the research in the metaverse subject in teaching activities, working within a multidisciplinary class of engineering and architecture students. The goal is to learn how to reach a Society 5.0 able to take care people with different disabilities (here, 'frailty') using an integrated scientific and humanistic approach. Between reality and fantasy, a hub in the mountain of the NODES metaverse was constructed to allow students and professor to communicate and verify all the projects developed during the semester of the "Virtual Reality and frailty" course. Twenty-three projects have been developed focused on both, people with different frailty and caregivers, focusing in a mountain digital and sustainable. The final metaverse demonstrates that students can develop 3D environments with high levels of interaction for both treatment/rehabilitation and entertainment. This indicates that there is a new way of teaching that must be investigate among new challenges at university level in both technical and humanistic domains without limits of time, space and material.**

***Keywords* — Metaverse, Digital Twin, Virtual and Augmented Reality, 'Frailty', Society 5.0**

I. Introduction

Since in 1992 Neal Stephenson coined the term Metaverse in his novel Snow Crash [1] as a world where virtual and reality interact and create value through various social activities, much research has focused on it as a frontier promising to revolutionize the way people in the future will be able to connect and interact in the digital realm.

Despite the term has received increasingly attention, a commonly accepted scientific definition is currently not available. Some people consider the metaverse to merely be a new term for Virtual Reality (VR) or Augmented Reality (AR), but for Park et al. [2] it is much more, as demonstrated also by other authors from both academy and industry. According to Cheng et al. [3] and Newton [4], the metaverse could become the next generation of the Internet and thus establish Web 3.0. Instead, for Ball [5] the metaverse is a massively scaled and interoperable network of real-time rendered 3D virtual worlds which can be experienced synchronously and persistently by an effectively unlimited number of users with an individual sense of presence, and with continuity of data, such as identity, history, entitlements, objects, and communications.

In the context of Society 5.0, a human-centered society merging cyberspace with physical space [6], metaverse has many possible uses in the medical fields [7], improving access to care, providing more immersive and interactive training experiences, and even creating new ways to treat diseases. Moreover, it has also been investigated as a potential engineering challenge because to implement ideal metaverse applications requires several scientific features [8]. Above all: (i) Incorporation of avatars, creating digital avatars of oneself as a way to express one's emotions and feelings uniquely; (ii) Blockchain-based operations, allowing consumers to safeguard their virtual assets and giving them digital proof of ownership; (iii) Use of virtual land, purchasing by anybody for cryptocurrencies as Non-Fungible Token (NFT); (iv) Immersive experiences, allowing immersive experiences that converge reality and the virtual world by utilizing mixed reality and AR/VR technologies; (v) Intersection with Artificial Intelligence (AI), including content analysis, self-supervised speech processing, robotic interactions, etc.; (vi) Reliance on Human-Computer Interface (HCI) technology, integrating user activities into the virtual world.

On the other hand, the integration of activities and methods requires a definition of metaverse suitable for the Generation Z (*Zoomers*) [9], to guarantee a sense of a virtual world based on daily life where both the real and the unreal coexist. One way is to refer to the metaverse as the virtual world in which the avatar (the user's alter ego) acts, becoming the subject. To this end, metaverse has a similar meaning to the digital twin in manufacturing, used to create real object virtually to represent the complex behavior of the system, also considering the possible consequences of external factors,

human interactions and design constraints [10]. For example, in 2022, Lv et al. [11] [12] showed that (i) metaverse is the expansion of Digital Twins in the fields of people and society; (ii) metaverse objects can be at the micro-, meso-, or macroscale integrating tangibles with social relations, such as interpersonal (friends, partners, and family) and social relations (ethics, morality, and law). Moreover, in 2023, Mitra [13] presented the recent (post-COVID) interest of academic community to investigate metaverse for education and training, implementing the ideas and concepts of the natural/physical world typical of a Digital Twin in a Metaverse-based education to make education more realistic and user-friendly.

Furthermore, the increase in life expectancy has pushed active and healthy aging as one of the global health priorities [14]. The World Health Organization (WHO) has designated the years 2021 to 2030 as the 'Decade of Healthy Aging' [15]. This initiative aims to lower the risk of chronic health conditions that adversely affect quality of life, increase health and social care services usage, and elevate costs. It promotes political and social interventions specifically designed for older adults, to raise awareness on simple healthy habits that can reduce frailty. The term 'frailty' has been used in several contexts over time, but its modern usage in medicine can be traced back to the 1990s [16]. While there is no single universally accepted definition, frailty is generally understood as an age-related state of increased vulnerability, characterized by the gradual loss of physiological reserves across multiple systems [17]. Being a multifaceted situation, the only way to address frailty involves a comprehensive and multidimensional approach aimed at improving the health and well-being of frail individuals [18]. The key objectives include: (i) Identification and assessment, recognizing frailty and pre-frailty early through screening and comprehensive geriatric assessments (CGA) to understand the individual's health status, needs, and risks; (ii) Multi-domain interventions, implementing interventions that target multiple areas, including physical health, nutrition, mental health, and social support; (iii) Personalized care plans: developing tailored care plans that consider the unique circumstances and preferences of each individual, ensuring that interventions are relevant and effective; (iv) Preventive strategies: focusing on prevention by addressing risk factors associated with frailty, such as social isolation, mood disorders, and lifestyle factors like excessive alcohol use or smoking; (v) Integrated care: enhancing coordination between healthcare providers, including geriatricians, allied health professionals, and social services, to provide holistic care that meets the complex needs of frail older adults; (vi) Monitoring and follow-up: establishing regular follow-up to monitor progress, adjust care plans as needed, and ensure that interventions continue to be effective over time.

Therefore, there are several current challenges to the creation of a metaverse platform able to be used among people in a university classroom in term of both, new cross-sectorial contents and low-cost technologies as well as in term of interdisciplinary approach, technical and humanistic, without limits of time, space and material.

This article describes the results of the teaching activity that has been carried out in the last years at the Polytechnic of Turin in the context of the course "Virtual reality and frailty", testing practice experiences and exams in the metaverse as design opportunity to augment the realty for frail individuals in the context of Society 5.0. The starting point was twofold: (i) a detailed review of the literature on the frontiers of the two main domains considered, digital representation and digital health for frail individuals; (ii) an aerial point cloud of the Cervo Valley Mountain realized within the NODES project.

The frailty of individuals was the topic at the center of the interdisciplinary teaching activity proposed. Thanks to the synergy between different disciplines - technical and humanities - the potential of the metaverse has been explored using digital tools in designing shared and interconnected spaces in which users can interact through their avatars. "*Augmenting reality with virtuality*": this was the purpose of the training experience that aim offer entertainment activities for those suffering from debilitating diseases through a path built for therapeutic or entertainment purposes in the metaverse. During the semester, professors, assistants and students, equipped with visors for VR (Quest 3), modeled fantasy environments and behaviors in the Cervo Valley of using to experiment entertainment and cybertherapy activities.

On the basis of frailty identified by each group and technologies adopted by the classroom, students learned how to approach a problem using a learning by doing methodology, virtually, in the metaverse. From lectures to exam sessions, teaching took place in the metaverse with teachers also present in the virtual reality modeled by the students. It all starts during the first lesson, when a patient in a wheelchair due to Amyotrophic Lateral Sclerosis (ALS) was invited to "have tea" in a mountain cabin reachable with a 45-minute walk in the woods (like the house of Heidi's historical memory), using immersive VR to move from the classroom to the kitchen using a 360° photograph in the metaverse, "with the orange kettle".

Fig. 1. The challenge for students: to use the metaverse to move frail people without limits of time, space and material.

This will be useful to students in the future, when as architects and engineers they will have to tackle all sorts of projects (from IT to aerospace, from mechanics to energy, from architecture to construction, etc.), always with a particular sensitivity towards vulnerable people according with Society 5.0 collecting data from the "real word" and processing by computer, with the results applied in real world.

II. Methodology

Society 5.0 is a digital society in which technological evolution has the well-being of people as a fundamental priority [6]. In this context, VR represents a form of communication that, using interactive and simulation tools, offers new opportunities for rehabilitation and entertainment

for people with different frailties (Autism Spectrum, Amyotrophic Lateral Sclerosis, Multiple Sclerosis, Parkinson's disease, Alzheimer's disease and Senile Dementia, etc.).

This topic must represent a fundamental cultural and professional background for an engineer or an architect who aspires to be responsible for strategic and organizational decisions, because it provides a pretext for guaranteeing a methodological "problem solving" approach based on creativity and critical thinking: taking into account the characteristics of people, an innovative technology is used to evaluate alternative paths for the solution of a given problem.

Since in the future, thanks also to the development of technologies, the world of work will change and many professional profiles will not be those of today and little is known about which will be the most requested, an appropriate ability to identify and solve complex problems, always with attention to people, represents an opportunity to intervene with one's own contribution in the flow of events that will influence the world of work in the coming years.

In this context, exploring the metaverse challenge and the emerging frontiers of digital health allows for a motivating interaction between both, interdisciplinary research and educational experimentation, starting from the difficult question "Healthy aging, frailty and digital health technologies: is the metaverse the next frontier?".

During the last year, a total of 24 groups were formed, each consisting of six students with different background; for each group a particular frailty was then identified, and the virtual space was modeled according to the specific needs of the people affected by that pathology of for their caregiver.

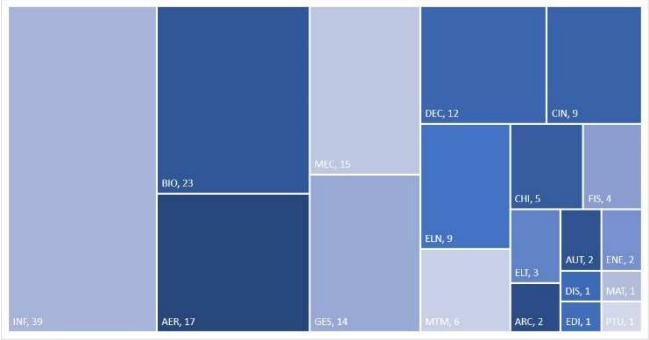

Fig. 2. Students' background.

In the context of the teaching activity described in this paper, "Digital and Sustainable Mountain" starts from Heidi, the cartoon that talks about inclusivity in a natural way, thanks to the protagonist's relationships with the blind grandmother of her best friend Peter and Clara, a 12-year-old girl confined to a wheelchair by polio. The challenge of being able to spend time in the mountains doing stimulating activities was launched to all the students at the end of the first lesson by a patient who, with his wife and family, had to completely change the paradigm of family life from the moment he was diagnosed with ALS.

In order to guarantee to work correctly, a virtual exhibition space for student projects was designed using the Spatial.io platform, where we created a 3D virtual hub for avatar interactions, presentations, and the display of exam projects. The goal of this space was to create an open environment for students and professors to share and explore the projects developed during the course. Spatial.io was selected for its ease of use and accessibility, as it is a free online metaverse that enables anyone to create their own worlds. Additionally, the Spatial metaverse can be accessed via the Quest 3 headsets provided to students for their project development.

Access to the space is granted by creating an avatar using personal credentials. Avatars can be customized according to individual style preferences on the Ready Player Me website. Once created, the avatar allows navigation through both personal virtual spaces and those of other users.

The meeting and exhibition space was designed as a suspended platform resembling a park, around which 24 small circular platforms are arranged. These platforms serve as stations for the presentation of student group projects. Each group created a portal leading to their virtual world and placed it on their group's platform.

Fig. 3. Platform for the presentation of student group projects.

This environment was developed through the following design steps.

1. **Modelling**. The initial design phase involved 3D modelling of the desired space and all the elements that would make up the future virtual world. This modelling was done using Blender, a software used to create the platforms.

2. **World Creation**. To create a new world in Spatial.io, one simply needs to select the "+ New Space" button on the main page and access the "Creative Toolkit" section. This toolkit provides instructions for using the Spatial Creative Toolkit plugin through Unity Engine. During this phase, the necessary software must be downloaded and linked to the Spatial.io account to begin world creation.

3. **Content Development**. The 3D model of the platforms was imported into Unity, where the ground was made walkable for avatars by adding a collision component. Scene content, such as grass and trees, was then created using assets downloaded from the software. These elements contributed to further customizing the environment, creating a unique and immersive learning experience.

4. **Lighting Management**. Ambient lighting and the skybox were utilized to customize the scene's colors and create environments with different light intensities, enhancing the overall atmosphere.

5. **Testing**. Once the scene was completed, it was tested online through the Spatial.io account to verify the scale of the models and the interactions created. Testing is crucial in the development of virtual reality projects, as it allows for the assessment of spatial perception through the headset and helps prevent the creation of environments that might induce motion sickness.

6. **Publishing**. Upon completion, the virtual world was published. During this phase, the option was provided to make the world public or accessible only via a link. We chose to share the link exclusively with the course students, who were able to upload their projects into the world by adding portals.

7. **Use of VR**. During the exam, students and professors used Quest 3 visors to connect and view the projects within the metaverse. To access the virtual worlds, users needed only to connect the headsets to a stable internet connection and download the Spatial.io application onto the headset. A high-performance Wi-Fi network was used to ensure a smooth and uninterrupted experience. The platform is also accessible from both desktop and mobile devices, allowing for flexible participation.

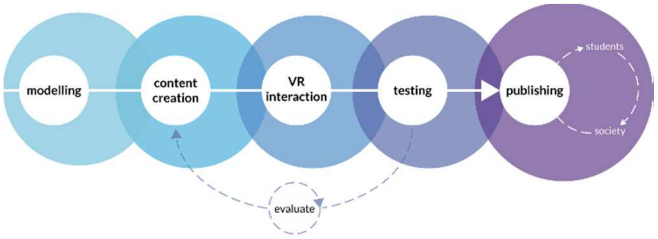

Fig. 4. Learing by doing activities in the metaverse.

Despite the increasing adoption of the metaverse in commercial applications, a considerable research gap remains in the academic domain, which hinders the comprehensive delineation of research prospects for the metaverse in healthcare [7]. As demonstrated by this paper, merging the digital and real worlds, the benefits of the metaverse in healthcare are manifold and the interaction with engineering and architectural projects needs to be deepened. What must be paid attention to is that normally health services typically revolve around human interactions and patients have conversations with physicians regarding their health condition. The metaverse can augment reality, but it cannot replace it.

III. Results

Digital health has been recognized as a valuable tool for supporting the self-management and well-being of older adults in their home environments. While the concept lacks a single, definitive definition, the World Health Organization (WHO) described it in their Global Strategy for Digital Health 2020–2025 [14] as "the field of knowledge and practice associated with the development and use of digital technologies to improve health". Digital health can enhance active and healthy aging by extending time in the workforce, reducing social isolation and loneliness, facilitating access to public and private services, and encouraging independence [19] [20] [21]. It encompasses a range of technologies, including smartphone and tablet applications, websites, connected devices, video consultations, and wearable tracking devices. These technologies allow healthcare providers to engage with older adults, motivate them, and promote healthy lifestyle behaviors [22].

Although several reviews describe various digital health interventions for older adults, there is inconsistency in the conditions addressed, types of interventions, and evaluation methods. Specifically, digital health interventions targeting frailty care are scarce and often lack effectiveness assessments, compounded by the lack of consensus on the definition of 'frailty' and insufficient scientific evaluation of their benefits for reversing frailty and/or improving quality of life [23]. Another possible limitation is that People Living with Frailty (PLF) are more likely to be excluded from the digital world than the older general population [24] due to the presence of cognitive and motor limitations that can significantly affect their ability to use human-computer interaction devices (i.e. controllers, joysticks, etc.).

What is described in this paper is an experiment, offered to the university students (second year of a bachelor engineer or architecture course), that investigates the topics covered in the course with a new approach, able to simulate the expected results in an alternative, virtual and immersive reality. We are therefore talking about metaverse: the participants, through the use of special viewers (Quest 3), have faced digital modeling in relation to the type of frailty chosen.

Fig. 5. Exams in the metaverse.

Humanity was the hallmark of the experience, empathy was the reason that guided the various activities implemented by the students: an example of cutting-edge training, which combines technical skills with the ability to experience emotions and a sense of responsibility towards others, especially those who, compared to us, need more care and attention. With the ultimate goal of training "all-round engineers", capable of designing public spaces with precision and at the same time protecting those fragilities - of whatever type they may be - that exist within our society.

The metaverse experiences created in the context described in this paper are mainly based on the models produced by students. For sure, the power system of pieces of information derived by the Internet in term of library objects, data or interaction in real time is not so dynamic as could be possible in projects that use platforms able to offer different capabilities (e.g. Decentraland) [25]. But this wasn't the goal of the teaching activity. In fact, Spatial.io has been selected to enable the building of immersive virtual spaces that can be accessed via a VR headset during the exam.

IV. Conclusion

To reach the results shown in this paper, a few years ago, professors at Polytechnic and University of Turin (Italy) accepted a 'big challenge' in the health domain: create greater interaction between engineering sciences and humanities and social sciences. A few years later, a colleague from California Polytechnic (US) also joined. Within the "Virtual reality and frailty" course, the collaboration between professors of Engineer and Architecture and professors of Neuroscience was an opportunity to stimulate multidisciplinary research on VAR for an increasingly significant impact on the territory and the community. Results are under testing with different typologies of patients, above all ALS and autism spectrum [26] [27] [28].

As a future work, based on the experience done and in line with what is described in the international literature about potential role of the metaverse for SDGs in developing countries [29] [30] [31], since the metaverse technology and its applications in education will represent a milestone for both education and communication globally, a PhD position has been funded at the Politecnico di Torino to develop the 'metaPolito' by utilizing a socio-technical design approach. This will contribute to improve the universities in the metaphysical environment to communicate via Avatar inside the 3D virtual campus and enjoy a unique experience with countless tools.

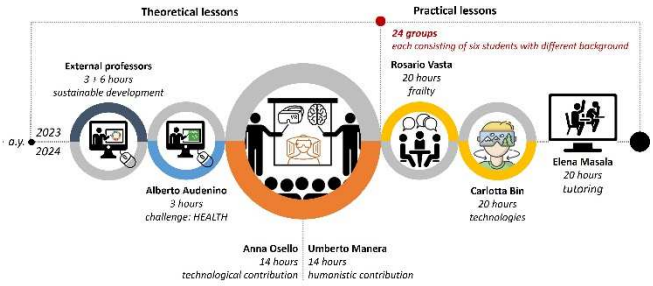

Fig. 6. Organization of teaching.

In addition to this, future work should include an improvement of privacy and data security concerns must be guaranteed, highlighting the importance of implementing safeguards to protect student information.

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