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IMUV: A Digital Twin for Mediation to Discover and Exchange on Territories

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ABSTRACT:

Urban digital twins are becoming increasingly popular across various domains, including urban planning and studies of cultural heritage. However, current digital twins lack an important aspect compared to their physical counterparts: the ability to exchange, discuss, and mediate in a dedicated location around a specific object. We require a place where we can exchange with experts, similar to what we can do on a university campus, and support participative science. In this article, we propose IMUV, a flying campus integrated with the urban digital twin. IMUV not only supports 3D urban visualization but also provides an online space where users can exchange and collaborate in both the real-world and online environments. We describe the conception, development, and evaluation of the proposed platform, highlighting its potential to bridge the gap between physical and virtual urban environments and facilitate collaborative decision-making processes. With the evolution of modes of working, such as remote work, we are also studying how online spaces can go beyond simple video conferencing. This article presents a proof-of-concept that can serve as a basis for such studies.

Figure 1. The IMUV Flying Campus

1. INTRODUCTION

Urban digital twins (Weil et al., 2023) are increasingly utilized by researchers, urban planners, and government officials to represent, study, and comprehend city objects and the potential impact of proposed projects around a specific object in dedicated locations. 3D urban digital twins have the capability to virtually represent not only the horizontal expanse but also the vertical expanse, aiding in understanding issues related to constructing large buildings that may affect the visibility of landmarks from key locations within the city, such as tourist destinations or points of historical interest. However, not all feedback can be obtained solely from subject experts; input may also be required from residents closely associated with or impacted by a project.

Over the past several years, there has been a growing utilization of citizen science and participatory approaches in urban planning. It can be challenging to convey project plans to citizens effectively. In such cases, the virtual 3D equivalent serves as a pivotal tool, enabling citizens to visually assess the impact of projects in their locality firsthand.

Online applications like Second Life (Kaplan and Haenlein, 2009) or the recently revived (or announced) metaverse applications (Wang et al., 2023) have sparked a significant revolution, enabling people to propose virtual worlds, interact with others, and develop elaborate plans for their planned virtual towns and cities. These platforms have demonstrated the potential of gaming and web (or mobile) applications to facilitate users in easily sharing their viewpoints through diverse mediums such as text, audio, or video. The goal of this article is to propose an online tool that can serve not only as a visualization tool for the 3D representation of cities but also as a space for exchange and contemplation. Such a platform must allow concerned individuals to convene online or in the real world and engage in discussions or exchanges around specific topics or projects.

We require a common space for collective thinking about the city and its various potential evolutions. This need emerged as a major requirement across different domains, especially during and after the COVID-19 pandemic, which led to the increased adoption of new modes of working, such as remote work (Ozimek et al., 2020). This space should serve as a real third-location, where exchanges can occur in different configurations, such as an exhibition hall, amphitheater, working space, co-creating space, and more. It should be a meeting place where different stakeholders can gather, each contributing their own expertise, including scientists, industry experts, local authorities, associations, citizens, and others.

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The objectives of such a project necessitate a thorough understanding of advancements in the fields of video games, 3D visualization of cities, and metaverse applications. The design and development of the platform should prioritize a reduced learning curve to ensure accessibility. The platform must facilitate easier knowledge exchanges related to cities, streamlined collaboration, and immersive experiences for users within the city and its associated data. Our proposed approach is in the intersection of a platform for research and exchange, video games, videoconferencing, virtual worlds and digital twins. The major challenge is to design or improve interoperable components that are used or identified. We also need to propose additional features on certain components. For example, this may mean triggering a videoconference on entering some specific zones.

To enable exchanges and collective reflections on urban topics, collaborative tools are essential. These tools should not only support discussions but also enable drawing and building objects (both 2D and 3D) of interest within the platform. Additionally, researchers could utilize the platform to showcase their data and associated simulations, such as demonstrating the vegetation capacity of different zones of interest.

This article introduces the design, development, and capabilities of the IMUV platform (Figure 1), facilitating exchanges and mediation. This type of platform aims to experiment with the various roles that such a platform can play. Section 2 provides an overview of the state of the art and recent technological advancements that have facilitated the development of such a platform, with a focus on standards and open-source components. The conception of the proposed work is explained in section 3, followed by the implementation elaborated in section 4. Section 5 outlines the results and capabilities of the IMUV platform. Finally, conclusions and future directions are discussed in Section 6.

2. STATE OF THE ART

Building virtual spaces for showcasing, exchanging, and mediating has garnered attention from various communities in recent years, including museums, historians, and urban planners. Throughout history, museums have served as places where people could visit and experience human progress, historical narratives, and advancements in art or technology. However, a significant barrier has persisted in the form of human mobility, as museums remain physical entities.

Virtual museum exhibitions (Bowen, 2000, Walczak et al., 2006, Styliani et al., 2009) have mitigated this mobility constraint, allowing people to experience museum collections from anywhere. With advancements in 3D technology on the web, particularly with standards like WebGL, accessing virtual museums has become increasingly feasible. In recent years, virtual museums have emerged without the need to physically move specific objects to another location, thereby reducing additional costs (Walczak et al., 2006). Regarding data formats, VRML, X3D, Web3D, and WebGL (Walczak et al., 2006, Styliani et al., 2009, Graf et al., 2015) have been proposed for the representation and visualization of 3D objects on the web.

Virtual worlds for events, meetings, conferences, and group discussions have become increasingly common. For instance, platforms such as Gather[1], Glowbl[2], Virbela[3], and Remo[4] offer online spaces for hosting meetings. Participants can engage through audio, video, collaborative boards, and screen sharing features. Some solutions, like Virbela, require users to download a desktop version. However, desktop-based solutions may lack accessibility across diverse platforms, including mobile devices. Furthermore, these solutions have limitations in integrating new collaboration modules. We aim to develop web-based solutions capable of supporting meetings while also facilitating the integration of city models for discussions.

Another significant development leveraging recent advancements in 3D visualization on the web (Krämer and Gutbell, 2015) is within the domain of urban planning and urban heritage. This field utilizes various standards such as 3DTiles, CityGML, PLY (Polygon File Format), X3D, COLLADA, and WebGL for representing city objects or objects of cultural significance. WebGL frameworks like X3DOM, three.js, Cesium, and iTowns play pivotal roles in visualizing 3D objects in urban digital twins (Samuel et al., 2023). 3D models of cities can be further extended to a full-fledged urban digital twins, integrating data streams and sensor data by using extensions of city information models (e.g., CityGML) like Dyanmizers (Chaturvedi and Kolbe, 2015) or versioning (Chaturvedi et al., 2017, Samuel et al., 2020) that can represent concurrent views of urban evolution.

However, the primary objective is to ensure that participants can easily interact with urban digital twins, surpassing mere 3D visualization and fostering collaboration while supporting participatory approaches (Marcus Foth and Hearn, 2009, T. Nochta and Parlikad, 2021) within these platforms. A major limitation of existing 3D urban digital twins and virtual museums is the absence of collaborative features that would enable users not only to access these platforms but also to share their viewpoints in various media formats, such as images, web pages, audio, videos, chat messages, conversations, etc. The aim of our work is to improve urban digital twins with these technological advancements in the field of collaborative tools (Figure 2).

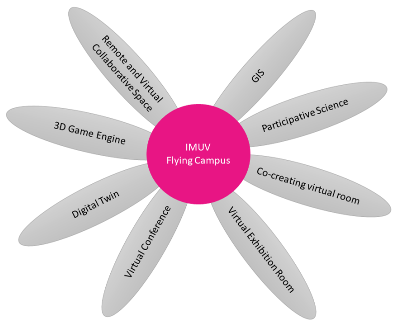

Figure 2. Requirements of the IMUV Flying Campus.

3. CONCEPTION

To respond to these requirements, we envisioned an online place, a space for meeting and exchange. We named it the Flying Campus, a virtual campus located on a flying island.

[1] https://www.gather.town/
[2] https://www.glowbl.com/
[3] https://www.virbela.com/
[4] https://remo.co/

We offer an innovative 3D web environment for the community, researchers, practitioners and citizens interested in urban development in various scientific fields. The IMUV's Flying Campus serves as a hub for exchange and mediation, focusing on the interrogation, simulation and visualization of territorial data. It is an experimental project that combines elements of urban digital twins with inspiration from video games, enabling the digital model to be augmented with data and simulations. In keeping with our desire to encourage exchange and observation, the campus buildings have been arranged to form a circle, creating a heart of exchange (the patio) and a path of observation (the path). Flying Campus users take on the appearance of avatars, and the application has been designed in a similar way to a video game to make it easy to learn. Whether in third-person or first-person view, users can evolve in the same synchronized virtual space.

The island flies over a 3D-modelled city, enabling users to benefit from and contribute to the progress made, particularly in the field of urban visualization. The pilot city chosen for this project is the metropolis of Lyon, however, the system is fully interoperable, enabling its potential replication in other territories. The choice of development tools is also crucial to our design process. All the tools used are open-source and for the most part part part of research projects, which has led to mutual enrichment of the projects.

4. IMPLEMENTATION

The development of IMUV[5] can be separated into two: the frontend and the backend. Both of them are developed using Node.js[6], a cross-platform JavaScript runtime environment. Available as an open-source environment, this ensured us to develop a vast majority of our platform, both for the client and server side of the IMUV platform using JavaScript. The frontend component of IMUV is available on the client side, i.e., the end users and the backend is managed by IMUV administrators. Both these components communicate using WebSockets.

The frontend is developed using open-source components like three.js[7] ITowns[8] and UD-Viz, the 3D visualization component of UD-SV (Samuel et al., 2023, Weil et al., 2023). three.js provides features like collision detection, animation, and handling media assets (like images, audio, videos, etc.). ITowns and UD-Viz are used for creating 3D visualization of the city as well its objects and for handling widgets. The gaming sub-component of UD-Viz also provides the necessary framework for the game engine and the necessary templates for the frontend and backend.

Figure 3 show the major components of 3D objects in the IMUV Flying Campus. The UD-Viz object, extending from the three.js object is a collection of component. A component consists of an ExternalScript, Renderer, Collider, and GameScript.

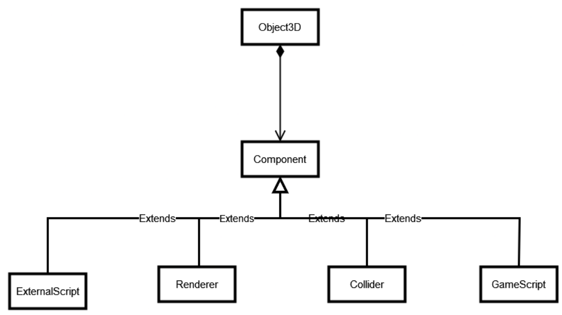

Figure 3. Components of 3D Objects in IMUV Flying Campus.

The **GameScript** component manages scripts for the game's internal context, handling aspects such as collisions, Object3D addition/removal, command management and the triggering of script events (e.g., initialisation, update).

ExternalGameScript component manages scripts for the game's external context, supporting rendering, user input, audio and the triggering of script events (e.g., initialisation, update). In a multiplayer game, the external game context generally runs on the client side, while the internal game context runs on the server side.

Renderer defines how a 3D object should be rendered visually in an external environment, specifying information such as its rendering model and color.

Collider defines the collision zones of 3D objects and manages their behavior when they collide in a 2D environment.

Furthermore, the IMUV Flying Campus contains multiple assets, like the 3D Model, Tiles, GameObjects, Sounds, Images, and Videos.

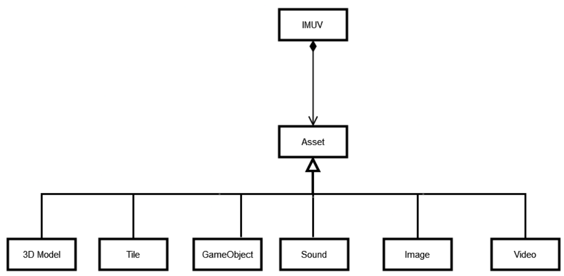

Figure 4. Assets in IMUV Flying Campus.

3D Models are 3D representations such as the island and avatars, stored in *.glb* format (a compact, self-contained 3D format that combines both geometry and textures in a single file).

Tiles are used to organize and display 3D geospatial data in an optimized way, particularly for buildings, in *.json* format (3D Tiles).

GameObject is a structure comprising several elements such as objects, external scripts, game scripts, rendering components, collisions, etc., stored in *.json* format.

Example **Sounds** include city sounds and game music, stored in *.webm* format. **Images** include images used for the showroom, panels, certain sprites (avatar face, butterflies), stored in *.jpeg*

[5] `https://github.com/VCityTeam/UD-Imuv`
[6] https://nodejs.org/en
[7] https://threejs.org/
[8] https://www.itowns-project.org/

and *.png* formats (PNG when transparency is required). **Videos** contain animated clips integrated into the flying campus, stored in *.webm* format.

The key aspects of the IMUV Flying Campus: Data, Standards, Multi-source visualization, Reproducibility, Users, and Collaboration.

Data : The first important aspect is the availability of data in the form of open data, sourced from various sources such as Grand Lyon, regional platforms like CRAIG, and national repositories like data.gouv. Additionally, data can be obtained from the research community, including simulations of pollution transfer or the detection of vegetated zones. These diverse datasets serve to enrich the digital twin, providing valuable insights into various aspects of urban environments.

Standards : It is crucial to develop an interoperable platform by leveraging norms and standards such as OBJ, GeoJSON, GLTF, and 3DTiles to ensure a seamless process of data processing and visualization. To achieve this, we utilize standards from organizations like ISO, the Open Geospatial Consortium, and BuildingSmart, including CityGML, WFS, WMS, and IFC. These standards facilitate compatibility and interoperability, enabling efficient handling and visualization of data across different systems and applications. The platform consists of modules, each composed of a set of interoperable components. Some modules are developed internally, while others are the result of local and national collaborations.

Multisource visualization : Certain data are transformed to a common standard to facilitate multi-source visualization. For instance, 3D data is translated to 3D Tiles format using the Py3DTiler component (Marnat et al., 2022). This standardization process ensures compatibility and allows for the seamless integration of diverse data sources for visualization purposes.

Reproducibilty and replicability : The utilization of container technologies such as Docker and Kubernetes, along with version control systems like Git, the configuration of infrastructure using OpenStack, and the implementation of Argo workflows, collectively ensure that the platform is not only reproducible but also replicable to other territories with minimal effort.

Users : Active users, including historians, researchers, citizens, and urban planners, played a crucial role in the development of the platform. The place was developed or co-constructed based on their feedback and input. Some of the aspects that were influenced by their feedback include projects related to intervisibility, sunshine analysis, etc.

Collaborative : The IMUV Flying Campus transcends the boundaries of a mere video game or a traditional 3D digital twin. Collaboration is the cornerstone of this platform, emphasizing a strong connection between the territory, gaming elements, and collaborative features, surpassing the features found in platforms like Second Life. To ensure a robust connection between these aspects, several key features are incorporated: video conferencing, content sharing, whiteboard sharing, etc.

5. RESULTS

5.1 Features

The IMUV flying campus (Figure 5) supports numerous features for discussion and mediation, through conference or exhibition rooms. In this context, we emphasize several virtual options mirroring the features of a physical conference. Participants are represented as avatars and can engage from various locations around the world.

Figure 5. Mini map of the IMUV Flying Campus. The areas highlighted with @ correspond to different rooms available on the campus.

Figure 5 depicts the green areas and various rooms on the campus. Users can utilize any pointing device, such as a mouse, and the keyboard to select a specific area and navigate inside or around it.

Island : The campus is positioned amidst the virtual model of the city of Lyon, creating the impression of a floating island with a dedicated conference campus. Figure 6 illustrates one such perspective, as a user gazes at the city of Lyon from the campus.

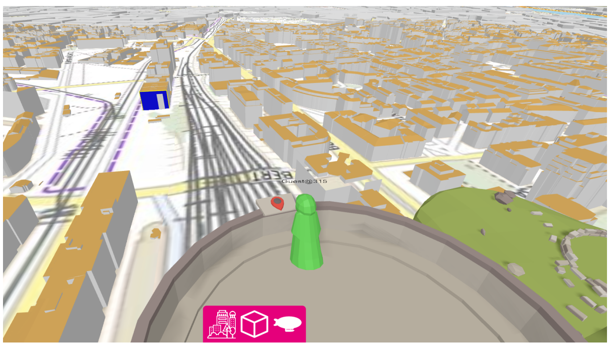

Figure 6. User looking at the city of Lyon from the Flying Campus.

Users have the capability to navigate around the island and explore both the green areas and the various panels available, as depicted in Figure 7.

Figure 7. User exploring the patio and the different panels in the campus.

Conference room : One prominent feature of the flying campus is the presence of a conference room (Figure 8) equipped with a large screen capable of sharing various types of media, including audio, video, and text. Virtual speakers also have the ability to share their screens. Virtual participants have the option to occupy seats in front of the conference screen. Additionally, conference participants can convene outside the conference room anywhere on the flying campus and engage in discussions with other virtual participants.

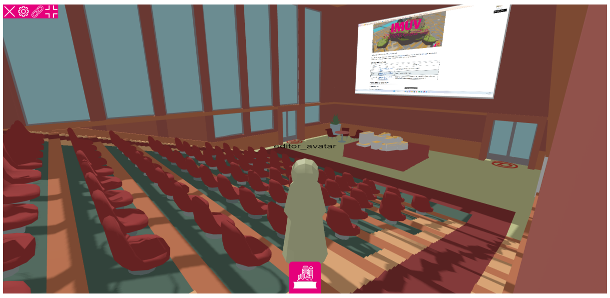

Figure 8. Conference Room with virtual participants

Another important feature is enabling users to place interactive panels on the island. These interactive panels could consist of links to various media types such as photos, videos, audios, or web pages. Users can interact with the media by using their pointers, for example, to play a video or audio (Figure 7).

Exhibition : Similar to physical conferences, the flying campus features a dedicated room for exhibitions (Figure 9). Consequently, conference participants can project posters or photographs onto the walls of the room. Other conference participants can utilize the guided tour to explore the displayed works using navigation buttons (such as next or previous).

Figure 9. Exhibition space spanning two floors.

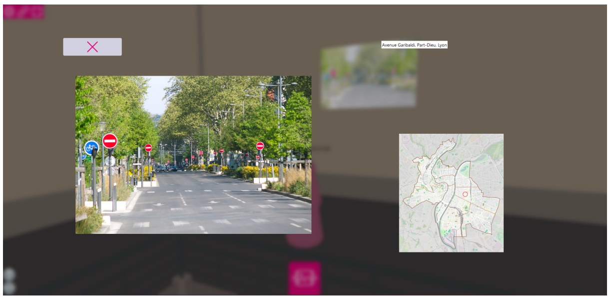

Figure 10. User exploring the guided tour.

They can also freely explore the surroundings by walking around and initiate their tour with any works of their choice. Figure 10 illustrates an example where the user has opted to start the guided tour and utilizes navigation buttons to explore the various works selected for the tour, as well as to view the details of any particular work in depth.

3D model : For the purpose of mediation within a designated area of interest under the flying campus, conference participants can specify the area of interest using a bounding box. Subsequently, the 3D model of the city appears in front of the conference screen, enabling participants to gather and discuss projects within the specified area in detail. This approach mirrors discussions around real physical models of new projects, facilitating urban planners and elected representatives to exchange viewpoints and provide feedback.

Zepplin : Participants may desire to travel to a specific area within the city to explore it in detail. With a Zeppelin (Figure 11), it is possible to travel around the city in the Zeppelin.

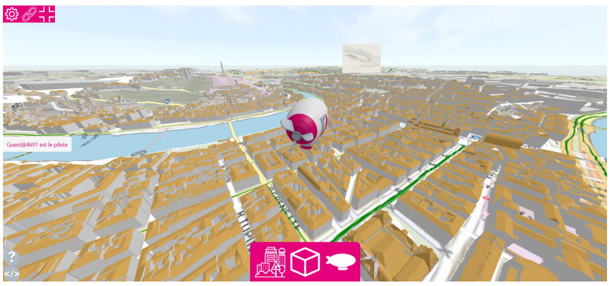

Figure 11. Traveling around the city using Zepplin. Here, the participant chose to travel to La Part-dieu in Lyon.

Studios : Another significant feature is the studio (Figure 12), where participants can engage in communication using a collaborative whiteboard to enhance discussions and even communicate via chat. The whiteboard and post-it notes in this space enable participants to utilize colored pencils for drawing and exchange ideas using diagrams.

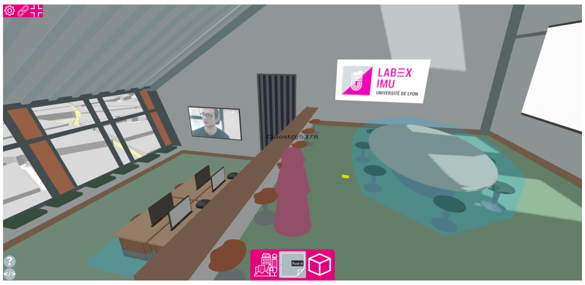

Figure 12. Studio in the Flying Campus for collaborative discussions.

These collaborative discussions are facilitated with the assistance of real-time collaborative discussion tools such as Jitsi (Figure 13).

Figure 13. Collaborative discussions using tools like Jitsi.

Widgets : By leveraging UD-Viz, the Flying campus also supports features such as selecting a layer (3D tiles, maps, etc.), a city object, obtaining the camera position, debugging 3D tiles, geocoding, and the ability to create new 3D objects in the 3D scene (Figures 14 and 15). These functionalities are valuable for various urban planning purposes, such as studying and discussing the impact of a specific object on the surroundings.

Miscellaneous Features : There are several other miscellaneous features, such as jumping from the Flying campus (Figure 16) and various games, that have not been described here due to space constraints. Nonetheless, these features also contribute to making the platform playful and engaging for mediation.

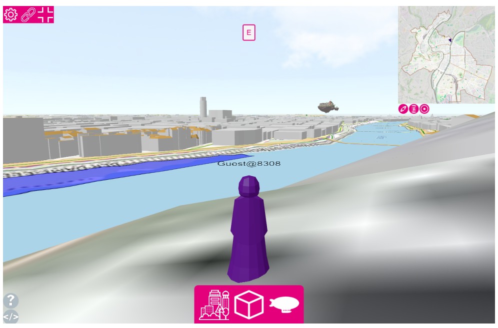

Figure 16. Jumping from the Flying Campus to a desired area in the 3D model underneath the Flying Campus.

5.2 Evaluation

The evaluation has been carried out in two different stages. In the first stage, the IMUV Flying Campus was presented to a wider audience (general public) at different events. In terms of the scientific community, we have shown it to members of the Maison des Sciences et des Hommes de Lyon Saint-Étienne (MSH). From a pedagogical perspective, it was presented at the École Nationale des Travaux Publics de l'État (ENTPE) and at the Intelligence des Mondes Urbains (IMU) Days. It was also featured in the Digital Twins competition at BIM World, where a special video[9] was created to present it. These presentations highlighted the Flying Campus and its functionalities in the field of virtual collaboration and urban visualization.

It has also been showcased at various events, utilizing both online and hybrid modes of presentation. For instance, during the Anthropocene week of 2022 held in Villeurbanne, the platform was demonstrated to participants to showcase its capabilities and gather additional feedback. During the event, the exhibition room was utilized to showcase the works of a resident artist from IMU. The photographs of the artist were exhibited not only in the physical space of the IMU campus but also in the virtual environment of IMUV. Participants could easily navigate through these works using a personal computer and the guided tour feature offered by the IMUV platform. This allowed for a seamless and immersive experience, enabling participants to engage with the artworks in both the physical and virtual world. Additionally, we collected feedback from the first page of the PoC, which comes with the tool.

During the second stage, we utilized the platform to comprehend how users interacted with this online space for their various requirements. Experiments were monitored, and the generated feedback enabled us to adjust the project's roadmaps. For example, suggestions were made to facilitate movement and improve image visualization in the Flying Campus virtual showroom. This feedback was invaluable in fine-tuning the functionalities and making the user experience even more fluid and rewarding. Now, we are ready to test this space with larger and more selected panels of experts.

5.3 Discussion

The experience facilitated by the IMUV flying campus can be considered to lie somewhere between serious games and the Metaverse (Wang et al., 2023). IMUV cannot be classified as a Metaverse platform as it does not fully embody Metaverse concepts (CRC, 2022). The primary objective of IMUV is to facilitate scientific endeavors addressing societal challenges. It provides a virtual environment for discussions surrounding scientific challenges and promotes collaboration among stakeholders. Through a participatory approach, participants can collectively work towards scientific objectives.

The goal of the IMUV Flying campus is to closely replicate the real-world experience of a physical conference. Participants can attend conference talks, pose questions, interact with others outside the conference halls on the campus, and even present their works in the form of posters or media. They can gather around 3D models and whiteboards to exchange ideas on city-related topics. Furthermore, the proposed platform, with its numerous widgets, can also be expanded into a full-fledged gaming platform, allowing participants to engage in various types of games during breaks.

[9] Présentation IMUV- Flying Campus: `https://www.youtube.com/watch?v=7NU3nX-nCk0`

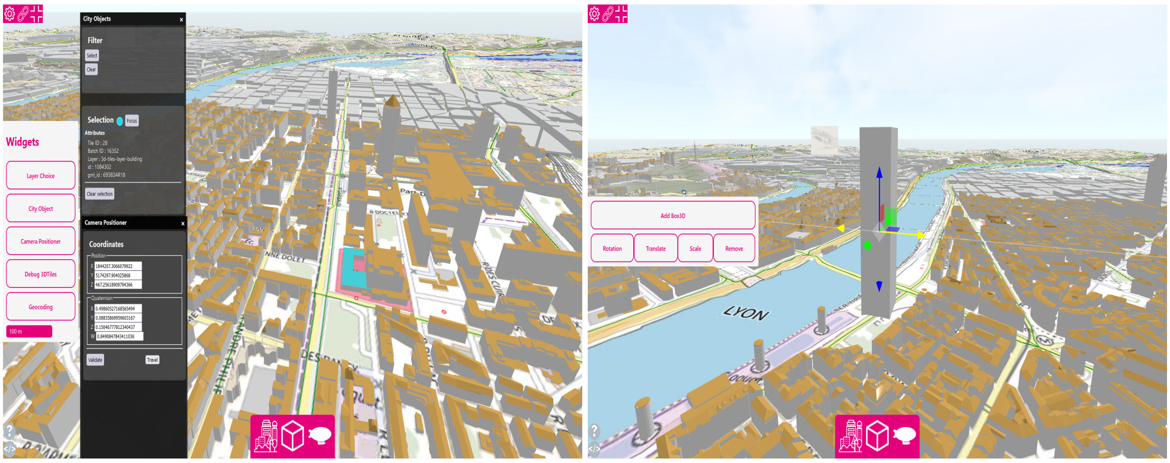

Figure 14. UD-Viz widgets in the Flying Campus. An example widget for creating new 3D objects for discussions.

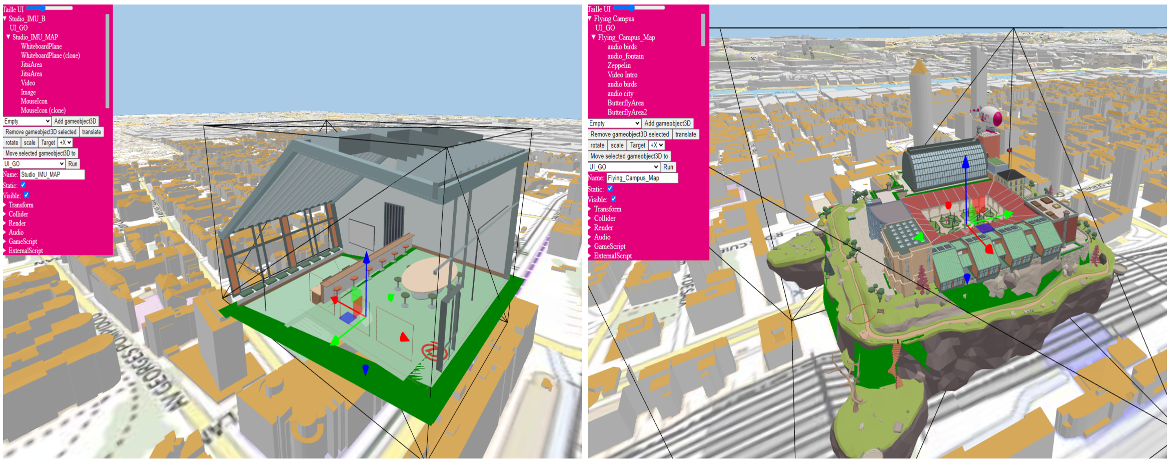

Figure 15. Creation of virtual worlds in the Flying Campus

However, the current version is limited in that multiple conferences cannot be hosted on the same server or instance. Specifically, there is only one instance for all users. Nonetheless, multiple conferences can be created by launching multiple server instances.

6. CONCLUSION AND FUTURE WORKS

Urban digital twins hold immense potential not only for visualizing city objects but also for showcasing past and future projects. With the support of collaborative features, usable in real-world, online, and hybrid meetings, the decision-making process is significantly enhanced.

In this article, we proposed extending the urban digital twin of Lyon with a flying campus floating over the city. The IMUV Flying Campus demonstrates an innovative approach where urban digital twins can serve as a mediation tool in online public spaces for participative science. Users can study and discuss complex problems more effectively by combining and providing expertise around a given topic. The first experimentation has been completed with promising results. Thanks to an open-source approach based on open-source components (extensible and reusable), our proposed approach is not only reproducible but also replicable for other territories.

The first experimental stage helped us identify new features that we are currently developing to enhance the platform with additional gaming features. This ongoing process will enable project proposers to incorporate gaming elements to encourage participation during project presentations and demonstrations, further enhancing the collaborative and interactive nature of the platform. Another area for future work is to explore how the expert panel will use the proposed platform for understanding territorial problems and decision-making by incorporating analytical tools in addition to human observations.

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