Connecting AR and BIM: a Prototype App

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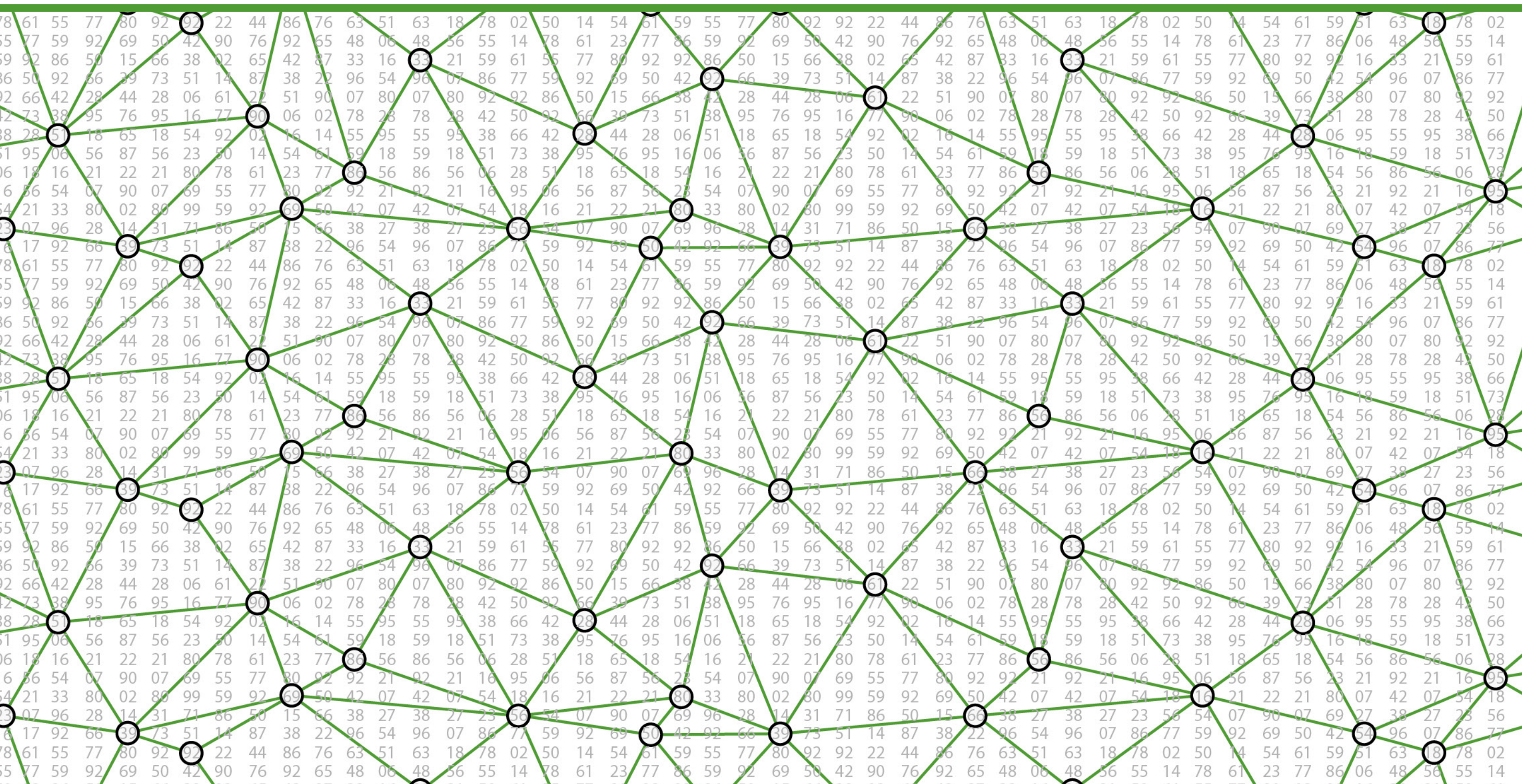
REPRESENTATION CHALLENGES
New Frontiers of AR and AI Research for Cultural Heritage and Innovative Design

edited by

Andrea Giordano
Michele Russo
Roberta Spallone



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Connecting AR and BIM: a Prototype App

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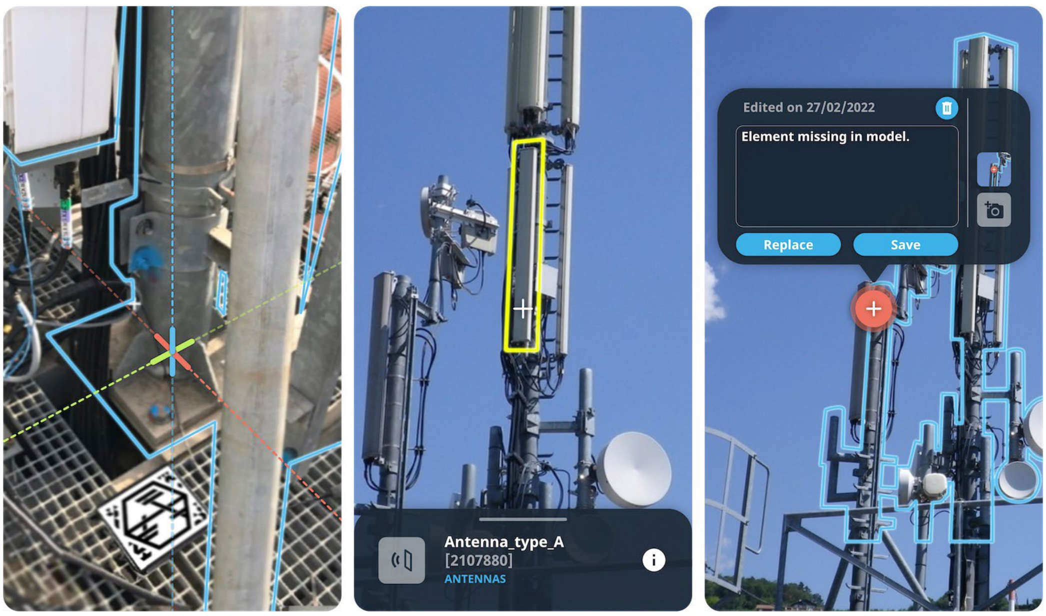
Luca Capozucca
Gianpiero Lops
Giulia Cicone
Roberto Rinauro

Abstract

This contribution discusses an ongoing project integrating information modeling and immersive technologies for the built space, in particular augmented reality (AR). We examined tools and procedures to quickly recognize the equipment present on telecommunication network sites and access the corresponding components on a digital information model. A first phase of the project, recently completed, produced an app prototype for mobile devices capable of showing a 1:1 scale AR representation on-site. The project highlights current limitations and opportunities in making the interaction between AR and building information modeling (BIM) technologies fully scalable.

Keywords
AR, BIM, AEC, project management.



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Introduction

By making possible an interaction with the digital object closer to the experience of reality, immersive technologies are innovating the management of architectural artifacts. In the architecture, engineering, and construction (AEC) sector, the visual juxtaposition of real and virtual objects can support the comparison of designed and built components, the systematization of on-site progress tracking, and, more generally, the symbiotic evolution of the building and its "digital twin" [Khajavi et al. 2019].
This contribution discusses an ongoing project integrating information modeling and immersive technologies for the built space, in particular augmented reality (AR). The project stems from a research contract between the Department of Architecture and Design of the Politecnico di Torino and the industrial partner INWIT, the first Italian operator of infrastructures for wireless telecommunications. INWIT operates an extensive network of antenna towers and related equipment. These assets have recently undergone a digitalization process, documenting the current state of the sites through building information modeling (BIM) and making data accessible through a corporate cloud platform (Fig. 1).
The partnership studies semi-automatic systems to recognize artifacts and support professionals and non-expert users during site surveys. Technologies such as AR and AI can support data query and update operations [Ahmed 2019; Ma et al. 2019]. In particular, we examined tools and procedures to quickly recognize or search for the equipment present on-site to access the corresponding components of the BIM model. A first phase of the project, recently completed, produced a prototype of an app for mobile devices capable of superimposing a 1:1 scale AR representation onto real-time imagery of the antenna towers site. The app will allow the user to view the 3D models of the company's BIM database, query data and metadata, and send reviews and reports to the BIM management team directly from the site through easy-to-use functions. The research also highlighted the advantages and limitations of solutions using the physical objects themselves as a target for setting the AR experience [Spallone, Palma 2021]. In fact, currently available technologies allow the recognition of architectural structures and equipment as reference points for positioning digital components, accurately superimposing them on real objects.

Background

With the development of mobile computing and the spread of mobile devices, AR shows growing benefits in the AEC sector, where more consolidated experiments and applica-

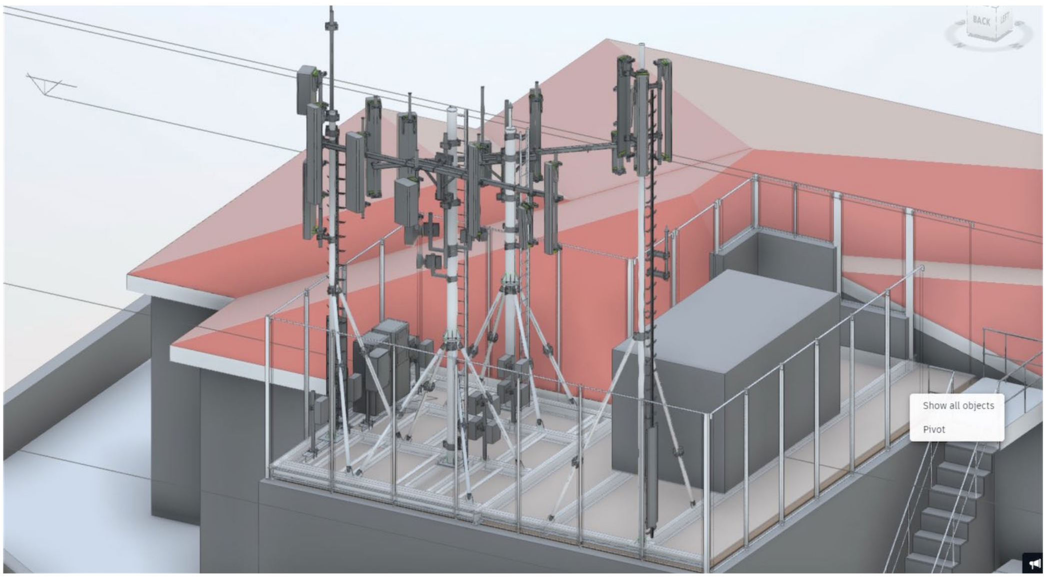

Fig. 1. Axonometric view of the BIM model of a site managed by INWIT (screenshot from the Autodesk Viewer web service).

tions are underway [Song et al. 2021]. AR allows superimposing digital layers onto camera images, simulating the user position relative to the virtual objects by tracking the observer's movements [Milgram, Kishino 1994; Amin, Govilkar 2015]. Hence, AR tools facilitate the search, exploration, and understanding of space-related digital information by making the experience closer to physical interaction. Some of the proven advantages for AEC applications relate to project communication and collaborative work, construction safety, process monitoring and progress tracking [Ahmed 2019]. The continuing development of headsets could make available cheaper and lighter devices than current products, giving new relevance to the use of AR, particularly on construction sites and in other contexts where safety is crucial [Sitompul, Wallmyr 2019].
Despite the high attention paid to these technologies and a recent "renaissance" of AR in construction [Chen, Xue 2020], this research field is still limited, especially when compared with other sectors. Although some experiments have been proposed [Garbett et al. 2021] the integration of AR and data-intensive cloud databases appears rare, notably for the management of BIM data [Chen, Xue 2020]. Features to work remotely on complex projects by accessing data from an immersive interface has yet to be incorporated into consolidated workflows and fully scalable systems. Though AR-BIM interaction is still not very present in literature and applications, researchers have highlighted how BIM and AR technologies can bring mutual benefits [Noghabaei et al. 2020]. For example, AR can improve communication between the different professionals involved in the management of a complex project and can facilitate the exchange of information between construction site and project. Furthermore, many commercial applications and development tools are still based on physical markers. This constrains the creation of a connection between real space and digital model to site-specific projects and design and installation costs, placing further obstacles to scalability.

Methods

The sites managed by the company show a wide variety of typologies, but the project focused on a subset of sites characterized by low-rise towers. Such sites host antennas on poles or small pylons, as well as other ground equipment, which include switchboards and power stations. It is therefore expected that the activities of the operators that we want to facilitate will take place on the ground and without the aid of special equipment. The most relevant elements in terms of standardization (e.g., antennas and electrical equipment) are also the most susceptible to alterations, such as replacement and reconfigurations. This allowed us to hypothesize advantages from automatic recognition tools.
In the first phase of the project, we analyzed different technologies for mobile devices to evaluate the compatibility with antenna sites and their management. We started by identifying a series of relevant parameters, values that can be measured on-site, and types of elements that may vary over time. We considered complex systems, such as those based on computer vision, and more straightforward ones, such as tools to let the user collect images or other data. Although the operational phases carried out so far have focused on augmented reality, the project is oriented to represent a discussion on the role of different technologies in the modeling and maintenance of the studied infrastructures and similar. The team selected two main categories of objects as priorities for the assisted survey functions: data devices and ground electrical equipment, such as switchboards and power stations.
The AR tools were found to be relevant for navigating information given its spatial position on the site, as in the case of BIM component attributes. Focusing on this technology, we have been developing an app for mobile devices that allows superimposing a 3D model onto camera images. The prototype app allows to navigate the company's BIM documents intuitively. We developed two main function classes. The first is composed of tools to identify components on-site, through search functions, or by exploring the hierarchical structure of the BIM model. The second class of functions concerns select-

ing BIM components in the 3D space to obtain data or produce reviews and reports. Much attention has been paid to the app scalability, which will have to be used on hundreds of different sites. The app and the server that allows it to work required the development of three main modules or components (Fig. 2):

1. The first module concerns the communication between the app and the BIM database.
2. The second is the graphical interface, and its development involves only the app.
3. The third is the AR module, and it too, to be scalable, requires communication with the server, as we will see in more detail.

Based on the solutions already adopted by INWIT to manage the BIM database, the Autodesk Forge platform was used for the model archive and the exchange of information from and for it. The mobile app is built in Unity, a development environment for cross-platform applications, popular in game development and suitable to build applications that make intensive use of 3D models. Finally, we used the Vuforia development kit for AR. This toolkit is compatible with Unity and supports many different anchoring systems.

Backend

The first module, allowing the app to communicate with the BIM model archive, employs the application programming interfaces (APIs) of the Forge platform to interact, in reading and writing, with the models collected on the company's server. Through the APIs, the server can receive requests to which it responds with a text message that can be easily interpreted by the client (in JSON format). In summary, the app will ask the server for information, such as sending changes to some selected parameters.
The workflow we developed specifically employs Forge's Model Derivative APIs. We have verified the possibility of bringing the metadata of a Revit project into the application through scripts in C#, which is the primary programming language for scripting in Unity. At this stage of progress, scripts have been tested with the Postman software. The JSON results have been inserted into the Unity app verifying the possibility of reconnecting the downloaded information to a geometric model for display.
The server will host not only the visualization models (that is, the 3D component of the models) but also the reference objects used for AR anchoring and tracing. Other functions hosted by the server will concern AR and should address the app scalability. For the tool to be usable in the various sites managed by INWIT, the digital models must be accessible through the server instead of being permanently stored on the app. Similar features are still little explored in the literature, and even commercial software tools offer limited possibilities for cloud storage.

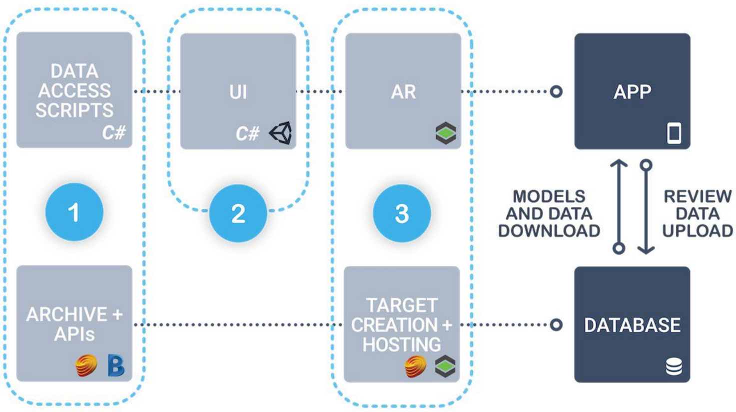

Fig. 2. Scheme of the structure of the app-server system.

AR Targets

AR targets can be images or more complex, large, non-standard targets. In particular, Vuforia allows the recognition of three-dimensional physical structures as reference points for positioning the digital layer (precisely aligning the latter and the actual objects). In this case, the targets can derive from digital reproductions of physical assets (meshes or point clouds). Currently, the project is validating a more typical anchoring system based on bidimensional targets, but we conducted the first tests on compatible 3D targets for Vuforia and carried out some preliminary assessments that may influence the development of the study. Mesh-based target models were the most studied option. The effectiveness was tested using small-sized models as targets. Our tests have found that target generation from BIM documents involves many processing steps. Hence, difficulties arise in automating the task, which, up until now, has been undertaken manually, using the graphical interfaces made available by Vuforia. The functioning of the targets on the site proved to be very sensitive to the discrepancies between the site and the models. We therefore assessed the solution as non-viable due to the accuracy of the models currently available to INWIT. Much work is still expected to identify the optimal targets, especially among markerless solutions.

Frontend

The app will include the following functions:

a. Recognition of the target and fine-tuning of the model position.
b. AR selection of elements through the exploration of physical space.
c. Selection of elements from a list and related AR highlighting.
d. Metadata editing and related AR highlighting.
e. Markup system.

Functions are based on the superimposition of the BIM model on the visualized space. These currently do not supply direct alteration and writing of new information in the BIM document. Only reading operations and the forwarding of reviews to the modeling team are supported. In this way, the communication process with the server is simplified, the risk of affecting the consistency of the database is limited, and modeling is entrusted only to expert personnel.

a. Recognition: at the current state of the project, the prototype employs QR-like bidimensional targets. The alignment of the model to the site is set by framing the target object. By pointing at the marker, the app obtains the identification code of the visited site and automatically starts downloading the correct model. Metadata, i.e. the attributes of the elements, are also downloaded. Alternatively (for example, in the case of damaged or not readable markers), the user will be able to enter the code manually. Once the target is recognized, the pattern appears superimposed on the camera images. Upon target installation, or following displacements or other correction needs, the alignment of the model to the real object can be refined directly from the app (Fig. 3). We have developed a system of sliders corresponding to the three coordinated axes and the rotation on a vertical axis to move the model to the correct position before activating other functions. The user can also confirm the last saved position without making changes. When fully operational, this system will require the association to each target of the relative position of the linked model. To further simplify the alignment procedure, the BIM modelers will first set up the expected model-target relationship. The subsequent on-site installation will take place within a certain tolerance (for example, within plus or minus one meter) and the commands on the app will only allow such slight corrections. One of the main critical issues concerns the management of larger sites, with structures and equipment arranged at distances greater than ten meters and sometimes at different levels. This problem can be addressed by allowing more than one target for each site.

b. AR selection: the ability to easily select elements as modeled in the BIM project is the main feature allowed by the AR tools. The goal is to let the user observe the site and at the same time obtain data from the information model. The developed system features a pointer that selects the element placed at the center of the device screen (Fig. 3). By making the mesh transparent, we can emphasize a single object, such as an antenna or an electrical panel, by showing only its outline. The result is perceived as a highlight around the physical object. In the prototype, a panel shows the identity of the highlighted element in real-time and allows the user to access the complete list of metadata and other related functions.

c. Selection from list: since, together with the geometric model, the app downloads the associated metadata, the user can also identify an object of interest from the list of represented elements. A textual query tool will simplify the search. AR will therefore allow the user to select an object while keeping its outline visible even when it is not under the pointer. In addition, a system of superimposed arrows will show where to move to find the previously selected object, even if it is not in the field of view (Fig. 3).

d. Metadata editing: the app will allow the operator to request modifications to the component's metadata. At the current stage of the work, no solution for the remote editing of instance parameters has been identified. Therefore, the use of a database of proposed alterations is planned. Changes will be shown in the element's attribute list view (Fig. 4). The new values will be displayed as the current attributes of the component, reporting whether the change has still not been confirmed and updated by the modeler. In this way, annotations are necessarily submitted to a second check by the modelers or site managers. Attribute alterations or a removal indication (if a modeled element is no longer present on the site) will also be highlighted in the AR view to keep track of the changes made. The already developed outline system can be used for this purpose (Fig. 4).

e. Markup system: the removal of an element can be managed through the metadata editing function just described. Adding elements to the model (due to a gap or an integration not yet registered) requires a system to indicate a position on the model not necessarily linked to a specific component. For example, to indicate that an antenna has been added, its anchor point on the pole could be selected. Thus, we propose a function to choose a hotspot on the model (Fig. 4). The issuing procedure will allow adding a written comment and some images, including the screenshot of the anchor point and any photographs taken by the user, also from other points of view. This information can be used by the modeler to create a draft of the modeled element, which can be integrated through subsequent surveys.

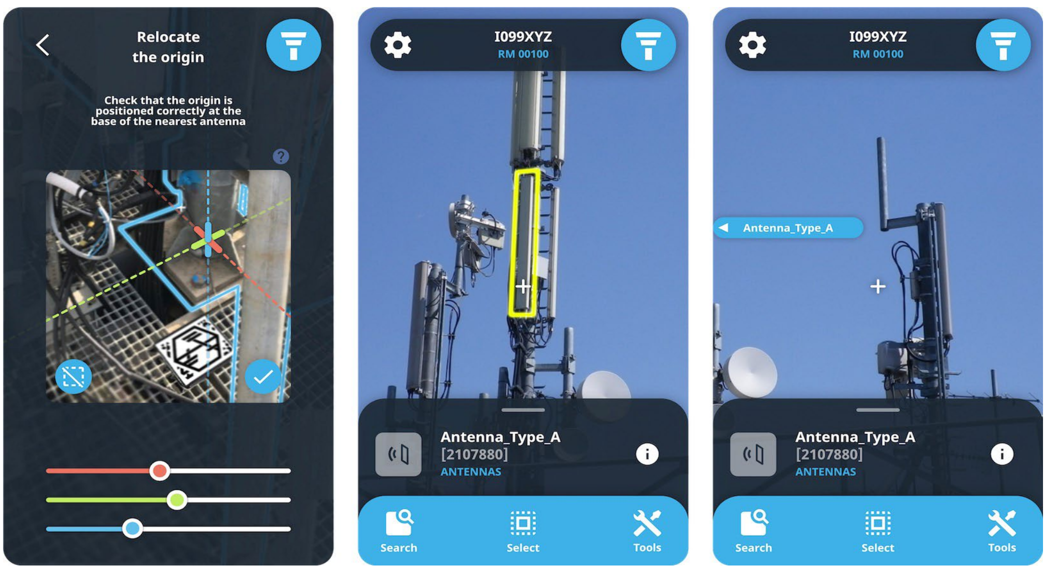

Fig. 3. Representation of the designed app functions. From left: fine-tuning of the model position; object detection and metadata retrieval; arrow indicating the selected object.

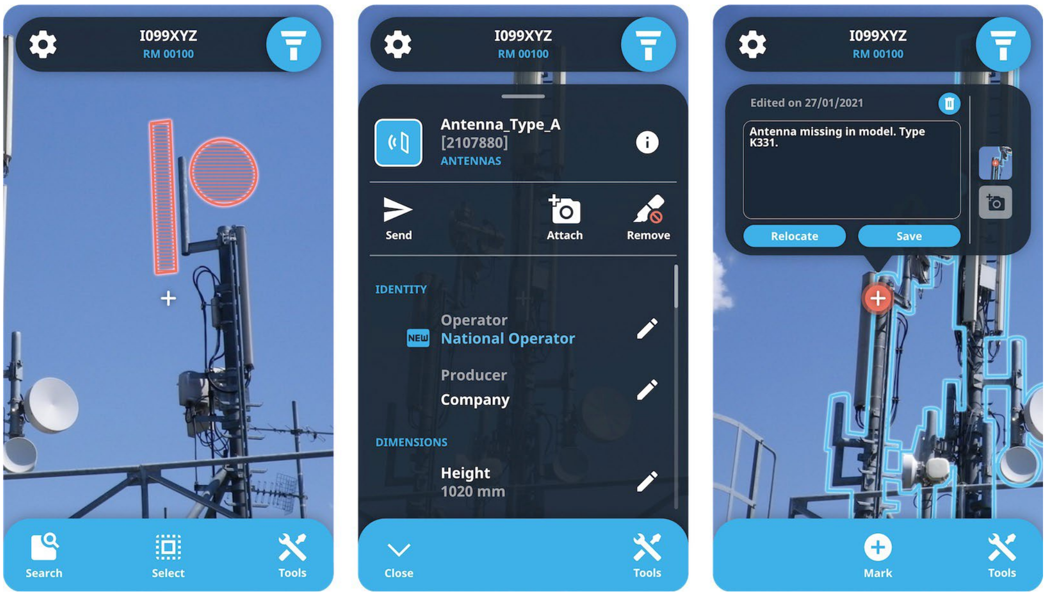

Fig. 4. Representation of the designed app functions. From left: hatching indicating removed elements in AR; metadata and editing functions; markup system.

Conclusions

This contribution described the development of an app prototype for the in situ analysis of 1:1 BIM models via AR, aimed at the management and maintenance of telecommunication antenna sites. The work made it possible to identify software procedures and tools available on the market to create an AR app compatible with a BIM database in the cloud and suitable for easily generated anchoring systems.

Results of the first phase of the project include the validation of three main modules of the app-server system. We discussed the development and compatibility testing of these modules, currently being realized separately. The first module demonstrated the compatibility of the Unity app with the Forge system for exchanging data with a BIM database. Future work will have to make the APIs fully operational on the mobile device to enable scalability. The development of the user interface component sought fluid and intuitive navigation of the model and its metadata. As for the AR module, we verified that the stability of the marker-based anchoring system is suitable for the intended purposes. Furthermore, different functions were tested to highlight elements and indicate if editing occurred.

The main limitation of the developed prototype concerns the use of physical targets produced *ad hoc*. The solution involves costs of design, installation, and maintenance. This choice will have to be re-discussed based on the diffusion of increasingly sophisticated markerless systems in AR development kits. A three-dimensional object recognition system based on natural features will allow defining the relationship between the site and its model remotely and in batch, and to avoid site-specific targets. In the oncoming research phases, we will evaluate in greater detail the targets to be used. In particular, a comparison between mesh targets and point cloud targets should be performed, addressing both the effectiveness of the AR experience and the possibility of batch-generating the targets.

In conclusion, the project laid the foundations for continuing research on critical aspects that still limit the adoption of BIM-enabled, fully scalable AR applications.

References

Ahmed Shakil (2019). A Review on Using Opportunities of Augmented Reality and Virtual Reality. In *Construction Project Management. Organization, Technology and Management in Construction: An International Journal*, 11 (1), 2019, pp. 1839-1852.

Amin Dhiraj, Govilkar Sharvari (2015). Comparative Study of Augmented Reality SDK's. In *International Journal on Computational Science & Applications*, 5 (1), 2015, pp. 11-26.

Chen Ke, Xue Fan (2020). The Renaissance of Augmented Reality in Construction: History, Present Status and Future Directions. Smart and Sustainable Built Environment. In *Smart and Sustainable Built Environment*, 1(11), 2020, pp. 1-18.

Garbett James, Hartley Thomas, Heesom David (2021). A Multi-User Collaborative BIM-AR System to Support Design and Construction. In *Automation in Construction*, 122 (February), 2021, 103487.

Khajavi Siavash H, Motlagh Naser Hossein, Jaribion Alireza, Werner Liss C , Holmström Jan (2019). Digital Twin: Vision, Benefits, Boundaries, and Creation for Buildings. In *IEEE Access*, 7, pp. 147406-147419.

Ma Lei, Liu Yu, Zhang Xueliang, Ye Yuanxin, Yin Gaofei, Johnson Brian Alan (2019). Deep Learning in Remote Sensing Applications: A Meta-Analysis and Review. In *ISPRS Journal of Photogrammetry and Remote Sensing,* 152 (June), 2019, pp. 166-177.

Milgram Paul, Kishino Fumio (1994). A Taxonomy of Mixed Reality Visual Displays. In *IEICE TRANSACTIONS on Information and Systems*, vol. 77 (12), 1994, pp. 1321-1329.

Noghabaei Mojtaba, Heydarian Arsalan, Balali Vahid, Han Kevin (2020). Trend Analysis on Adoption of Virtual and Augmented Reality in the Architecture, Engineering, and Construction Industry. In *Data*, 5 (26), 2020, 26, pp. 1-18.

Sitompul Taufik Akbar, Wallmyr Markus (2019). Using Augmented Reality to Improve Productivity and Safety for Heavy Machinery Operators: State of the Art. In Spencer Stephen (ed.). *The 17th International Conference on Virtual-Reality Continuum and Its Applications in Industry*. Brisbane: ACM, pp. 1-9.

Song Yang, Koeck Richard, Luo Shan (2021). Review and Analysis of Augmented Reality (AR) Literature for Digital Fabrication in *Architecture. Automation in Construction*, 128 (August), 2021, 103762.

Spallone Roberta, Palma Valerio (2021). Artificial Intelligence and Augmented Reality: A Possible Continuum for the Enhancement of Architectural Heritage. In *DisegnareCon*, 14 (26), 2021, pp. 16.1-16.11.

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