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VIRTUAL REPRESENTATIONS IN IMMERSIVE ENVIRONMENTS TO SUPPORT CULTURAL SIGNIFICANCE ASSESSMENT

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ABSTRACT:

This paper explores the potential of virtual representations of the built heritage integrated in immersive web-based platform to support the work of experts in collecting, formalizing, and communicating data about its Cultural Significance (CS) in a participatory, multi-actor and multi-disciplinary processes. The suitability of the proposed framework is evaluated through a case study approach with the observatory of Cointe, located in Liege, Belgium. A survey was conducted in an existing web application to conduct this research with real data about values associated to the place by different groups and individuals. The taxonomy proposed in (Jouan and Hallot, 2022) is implemented to formalize the exported data. The ability of this formalism to move towards the quantification of qualitative data about cultural values is further evaluated. To do so, the potential of the data model to generate multiple meaningful representations of CS data while giving experts the necessary flexibility to focus on different aspects of interest is explored through traditional spatial analysis tools in GIS environment. The article also proposes an iterative method that supports the elaboration and progressive refinement of strategies for the recording of heritage places according to the evolving state of knowledge about its cultural significance.

1. INTRODUCTION

Assessing the cultural significance of a place is an essential activity that supports decision-making for the preservation and management of the built heritage. The choice of appropriate methods and tools to capture value judgments associated with a site is therefore critical to reveal the meaning of the place for all social groups involved and adopt sustainable conservation policies accordingly. The value shift discussed in (Avrami and Mason, 2019) progressively led researchers and practitioners in the field of heritage conservation to adopt multi-actor and multidisciplinary approaches to generate more holistic representations of the cultural significance of objects and sites. In this framework, community involvement through participatory processes gained interest in the last decades as it allows them to consider the views of all social groups and stakeholders concerned, going beyond the sole perspective of experts (Heras, Moscoso Cordero, Wijffels, Tenze and Jaramillo Paredes, 2019). Although the involvement of local communities in the preservation of their cultural heritage is critical to enhance and sustain the effects of conservation policies, reaching out to a representative portion of all social groups involved can be challenging in some situations, particularly in the case of inaccessible places of significance. In this regard, virtual copies of heritage sites and collaborative platforms can play a critical role in enhancing accessibility and participation regardless of the nature and duration of the inaccessibility. Such platforms allow us to maintain the link between a community and its heritage through virtual experiences that can contribute to transmitting associated knowledge while capturing key data to support experts in the value assessment process.

The ability of SLAM (Simultaneous Localization And Mapping) technologies to capture high-quality data while fastening the data acquisition process makes it a suitable alternative for the recording of heritage places. Recent research highlighted the enhanced acquisition speed enabled by SLAM sensors and the reliability of the data captured, despite the lower accuracy and geometric resolution in comparison with Terrestrial Laser Scanning (TLS) survey (Hess and Ferreyra, 2021; Pepe, Saverio Alfio, Costantino and Herban, 2022). The combination of SLAM with other recording techniques like TLS and photogrammetry benefits the digitization of heritage places as it allows to further optimize survey strategies. The recording of heritage places should be understood as an iterative process as its objectives and strategies evolve alongside the understanding of their cultural significance. At the inception of any conservation project, a first extensive documentation of the place is required to support experts in the preliminary studies and facilitate the collaborative management of heritage information by all stakeholders involved. SLAM technologies can play a major role in this regard as they allow capturing very large data sets with an appropriate level of detail for such a purpose. Besides enabling metric data extraction, point clouds can be used for 3D visualization of places in Heritage Information Systems (HIS) combining spatial, temporal, and semantic content (Poux, Billen, Kasprzyk, Lefebvre and Hallot, 2020). The integration of semantically enriched virtual copies of objects in virtual environments provides with new opportunities to collect data about values associated to a place by multiple stakeholders and therefore support the assessment of its cultural significance.

Considering the former, the integration of virtual copies of heritage sites in web platforms for 3d content visualization can contribute to optimizing interactions among actors along the conservation process. This approach opens new perspectives for the involvement of non-expert stakeholders in the conservation process. In this paper, we explore the potential of virtual representations integrated in immersive web-based platform to support the collection of cultural significance data. The objective is to investigate whether this approach can support the value assessment of heritage places as it enables stakeholders to retrieve targeted data in a dedicated formalism. The ability to

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generate additional meaningful representations of heritage significance based on the exported data is therefore crucial. To carry out this research, the framework was implemented in a web application and its suitability was evaluated through a case study approach. A survey has been conducted to collect real data about values associates by different groups and individuals to the selected case study, namely the observatory of Cointe, located in Liège, Belgium. This paper also proposes an iterative method that supports the elaboration and progressive refinement of strategies for the recording of heritage places according to the evolving state of knowledge about its cultural significance.

2. STATE OF THE ART

2.1 Cultural significance assessment of the built heritage

The Burra Charter (Australia ICOMOS, 2013) recalls that the goal of conservation is to retain the significance of a place. This postulate imposes to go beyond considerations related to the preservation of its original fabric and to recognize the meaning of heritage through the multiplicity and diversity of values associated with by all social groups concerned. In (Araoz, 2011), the author discusses the paradigm shift that occurred in the field of heritage conservation and depicts heritage values as a “vaguely shared set of intangible concepts that simply emerge from and exist in the ether of the communal public consciousness.” De la Torre discusses the progressive expansion of the concepts of heritage and significance and argues that “heritage is no longer considered to be a static set of objects with fixed meaning, but a social process through which any human artifact can be deliberately invested with memorial function” (de la Torre, 2013). In the current paradigm, heritage is indeed considered as a “politicized social construction” (Avrami and Mason, 2019) based on the recognition of values that are considered subjective, context-related, and therefore very mutable. As argued in (Araoz, 2011), although “values can neither be protected nor preserved," identifying these values and their “vessels” or carrier, is crucial to inform decision makers and orient conservation decisions. In the end, it is the role and duty of project designers to establish a project that will inevitably favor some aspects over others and that will itself generate new values.

Considering the former, value assessments should seek to provide a holistic representation of places and objects’ significance while highlighting the importance of the different values for all stakeholders’ groups. Even though qualitative methods should be implemented to capture the stakeholders’ impressions, it is essential to enable moving towards a form of quantification of this data to support decision makers and project designers in the prioritization of values and to enhance the communication of CS data to a wide audience. In this perspective, Jouan and Hallot argued that the integration of cultural significance data in HIS requires the adoption of a dedicated taxonomy. Based on an existing framework for cultural significance assessment (Fredheim and Khalaf, 2016), they proposed a data model that “organizes the encoding of targeted data with a high level of granularity, and therefore allows to retrieve tailored information about objects’ significance and to provide with multiple representations of this knowledge through specific data queries in HIS” (Jouan and Hallot, 2022). Their model (Figure 1) extends the Multiple Interpretations Data Model (Van Ruymbeke, Hallot, Nys and Billen, 2018), initially intended to support the elaboration of Information Systems (IS) in the field of Archaeology.

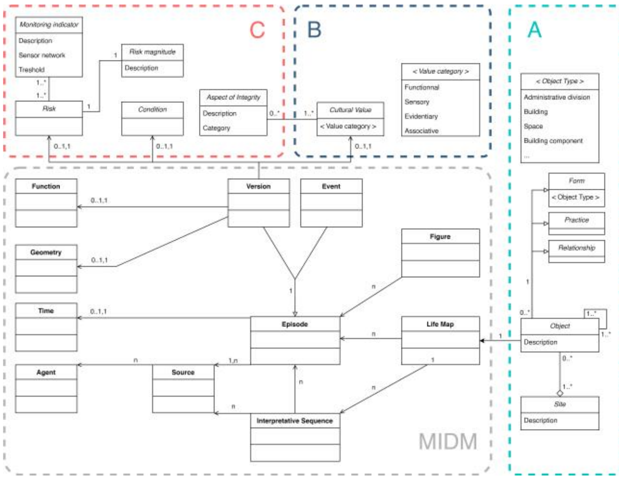

Figure 1. This figure shows the data model of Jouan and Hallot for the formalization of Cultural Significance Data in HIS.

2.2 Immersive environments and participatory approaches

The use of immersive and interactive digital environments in the cultural heritage sector is well established, especially in the museum and built heritage conservation sectors. They are implemented to fulfill different objectives such as to support educational activities (Andreoli, Corolla, Faggiano, Malandrino, Pirozzi, Ranaldi, Santangelo and Scarano, 2017), to enhance touristic experiences (Poux, Valembois, Mattes, Kobbelt, Billen, 2020), to give access to a knowledge base (Banfi, 2021), and to convey the significance of heritage sites and their components (Graham, Chow and Fai, 2019). In addition to supporting the dissemination of knowledge, Poux argues that such environments allow capturing data about visitors’ experience. In (Jouan, Moray and Hallot, 2022), authors elaborated a prototype of an immersive and interactive environment in a game engine that integrates multiple representations of the built heritage to inform users and collect formalized data about cultural values.

It has no doubt that the experience of stakeholders’ groups with the physical realm of heritage places is critical for the assessment of their significance, especially to enable them to grasp the sense of the place as well as for the identification of sensory and emotional aspects of value. Nevertheless, considering the myriad forms of inaccessibility of the built heritage (Hallot, Lambert and Jouan., 2021) and the necessity to adopt inclusive frameworks to encourage community involvement in the conservation and management of its cultural heritage, the use of digital copies in immersive environments can be complementary to traditional approaches. Indeed, they can be valuable assets for knowledge dissemination and value assessment activities, or simply to maintain the link between the site and communities involved at both local and global levels.

Considering the former, we assume that such digital interactive frameworks can support the work of experts in collecting, formalizing, and communicating CS data in a participatory, multi-actor and multidisciplinary approach (Heras, Moscoso Cordero, Wijffels, Tenze and Jaramillo Paredes, 2019). To verify such an assumption, we conducted a survey on two distinct groups to collect their value judgments about a specific case study. Furthermore, we implemented the data model proposed in (Jouan and Hallot, 2022) to enable data extraction in a dedicated formalism. In the end, we will also verify the ability of such taxonomy to support experts in generating multiple meaningful representation of CS data with the necessary flexibility to focus on different aspects of interest.

3. THE CASE STUDY

The observatory of Cointe (Figure 2) was built between 1881 and 1882 on the hill of Cointe which overlooks the city of Liege from the south. Located within the perimeter of a private residential park, it was the first construction on the site and the only property hosting a public function with scientific and cultural purposes. Belgian architect Lambert Noppius opted for the neo-Gothic style with obvious references to the medieval architecture. The building is divided into distinct entities with specific functions organized along multiple vertical points of inflection. Its geometry, spatial organization and aesthetic expression enhance the perception of its functional dimension. Red brick, blue limestone, and wood are the prevailing building materials in the façades of the initial construction. The building has undergone many transformations during its history to meet the evolving requirements of its users considering both the technological developments in the field and the evolution of the astrophysics department. Significant transformations were undertaken between 1937 and 1956 and gave the site its current appearance (Figure 3). Although the desire of visual consistency with the ensemble of 1882 seems to have guided most transformations achieved before 1956, these adaptations considerably affected both aesthetical and functional aspects of the building. The most noticeable adaptations are the almost complete reconstruction of the two wooden entities hosting the great equatorial telescope (1937) and the meridian circle (1946); the junction between the southern tour and the assistant building (1938-1940); the modernist extension (1959).

Figure 2. This picture shows the state of the observatory of Cointe somewhere between 1882 and 1937.

Figure 3. This picture of the observatory illustrates the main adaptations that took place between 1937 and 1959. Picture taken in 2022 by authors.

The site was abandoned by the university in 2001 and sold to the Walloon region after the relocation of the department of astrophysics to the main university campus. Due to the rapid deterioration of the buildings, a petition was launched in 2017 by multiple associations concerned with the preservation of local heritage, to call on local and regional authorities to adopt the necessary protection measures and to reflect on the site’s future destination. Despite the success of this initiative (more than 25.000 signatures were collected) as well as the reflections led in the faculty of architecture about the future of the place, the decision to sell the site was made in 2022 by the Walloon region.

4. METHODOLOGY

4.1 Iterative workflow for geometry recording

An extensive survey of the site was carried out adopting an agile approach to progressively adopt the documentation strategy according to the evolving knowledge about the site’s cultural significance (Figure 4). The initial objective of the survey was to produce a record that would support the work of experts and students in the preliminary study and the diffusion of knowledge about the site to a wide audience. Indeed, the observatory was abandoned after the relocation of the Astrophysics Department to the main university campus in 2001 and is no longer accessible without the authorization of the Walloon Region. Considering the former, it was crucial to reflect upon mediation strategies to maintain the link between the community and its heritage.

Therefore, it was first decided to provide a comprehensive virtual representation of the place with an appropriate level of detail for visualization purposes. To achieve this task, we opted for a mobile mapping solution to save considerable time in data acquisition and processing while ensuring a satisfying level of detail. We opted for the Navvis VLX 3D mobile scanner, a lidar-based SLAM system equipped with two lidar sensors and four cameras that allow capturing a point cloud of the environment with RGB data along with georeferenced panoramic images. Based on a combination of archival sources and in-situ analysis, specific features of significance have been identified and further documentation needs could be specified. Multiple documentation techniques were required to document these elements with the targeted accuracy and resolution. On the one hand, Terrestrial Laser Scanning (TLS) with the Leica BLK 360 was used to capture the geometry of the meridian circle and its building. On the other hand, aerial photogrammetry with the DJI Mavic Pro 2 allowed to generate the point clouds of the roofs and façades with an overall GSD of respectively 5 and 2 mm. A network of Ground Control Points (GCP) was established at the inception of the project to facilitate data consolidation and integration. The network surveyed with the Leica TS06 Total Station generates a closed loop around the whole site to enable controlling the quality of the captured data. Finally, the Trimble R2 GNSS receiver was used to obtain the coordinates of GCPs distributed across the site to enable georeferencing the final model in Lambert 2008 coordinates system.

Data processing and post-processing for the NavVis VLX data were achieved in IVION, the cloud-based NavVis platform for clouds processing, management, and visualization. The alignment of individual scans was performed in Leica Cyclone and photogrammetric reconstructions were achieved in Reality Capture software. Further point clouds editing, cleaning and classification was done in Cloud Compare. To facilitate data

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visualization and sharing, all point clouds were uploaded to IVION. The final record includes the point clouds of the park, the roofs, the façades, and interior spaces except for specific spaces that were not accessible during the survey for safety reasons.

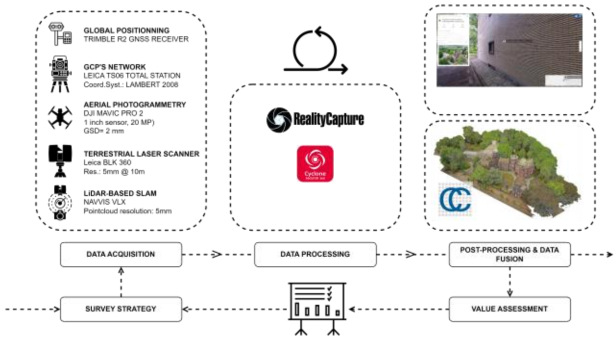

Figure 4. This chart illustrates the iterative workflow adopted for the survey of the observatory. It specifies the documentation techniques and technologies used for data acquisition as well as the applications exploited for data processing, post processing and visualization.

4.2 CS data collection

The aim of this research was to simulate a partial data collection process of heritage values associated by various stakeholder groups to a site to verify the initial hypothesis based on plausible data. The research objective was neither to conduct an in-depth study of the case study's heritage significance nor to develop a holistic data collection method for evaluating cultural values associated with this type of heritage. Further reflections on the duration and sequence of the data collection process, the representativeness of different stakeholder groups, and the methods used for data collection, processing, and interpretation would be required for these approaches.

In this epistemologically grounded research, we employed the constructionist paradigm in social sciences, specifically realistic constructionism based on the realist hypothesis as described by de Sardan (de Sardan, 2008). The study aims to construct social knowledge about a real phenomenon, in this case, the heritage significance of a site, by examining the perspectives of those who discuss it. The pursuit of veracity necessitates both logical and empirical rigor to meet various scientific criteria. Methodologically, the choice of data production methods was guided by the study's objectives and the need for consistency between collected data and the "reference reality" under investigation. The approach is both inductive, seeking to validate hypotheses generated from a review of relevant scientific literature, and deductive, aiming to generate new questions based on field-collected data, particularly if it challenges initial hypotheses. The data collection process implemented multiple methods from social sciences, both qualitative and quantitative.

A survey protocol was therefore established to acquire data about cultural values, the context of the survey and the profile of participants, formalized according to the taxonomy proposed in (Jouan et Hallot, 2022). The implemented protocol is a hybrid form of group investigation that integrates questionnaires to collect data on users’ experience and profile, among other things, with the purpose of capturing the consulted actors’ viewpoint through their observations. Several inherent elements of this method could affect the reliability of the relationship between the reference reality and the final scientific product. The data collection protocol implemented here was designed to mitigate the effects of identified biases on the adequacy report between the survey data and the targeted reference reality.

Some biases were related to the data used by researchers to conduct the experiment. For instance, most interviewed participants had never visited the studied site and only had knowledge of it through the survey's introduction and the virtual exploration of its geometric representation. Informing the participants about the place and the stake of its conservation allows to limit the risk of collecting stakeholders’ opinions based on misunderstandings or misconceptions. The information selected by researchers to introduce the case study is a factor that strongly influences the experience of participants. In this case, we limited the presentation time to 15 minutes to maintain participants’ concentration and we decided to focus our presentation on functional, historical and architectural aspects of the observatory. The presentation ended with a summary of recent news and developments concerning the site and its future. Although these choices clearly influenced stakeholders’ perception of the site, especially those who had never heard about the place before, these biases were not considered critical in this case given the purpose of the research.

Additionally, the recording of the site's geometry is subject to specific conditions and objectives that heavily impact the appearance of the final product, the perception of the place by participants, and the nature of their observations. Several stakeholders highlighted the importance of being able to visualize different states of the building over time and observe the site under varying lighting conditions. While these functionalities would undoubtedly add significant value to an exhaustive study of the cultural values associated with a location, they are beyond the scope of the current research and have thus not been incorporated.

Another bias is related to the choice of IVION platform. Indeed, our IVION license limits the number of users that can be registered on the platform, so we had to create a single user for each group of participants. This means that the data added by the participants appeared to the others as they updated the web page. Although it is not controllable, participants have been informed of this issue and have been asked not to consult POIs created by others to avoid such data influencing their own assessment.

Further developments will seek to tackle these issues and improve current mechanisms for retrieving data about users’ experience either by personalizing IVION’s interface through its API or by developing an independent and open solution.

4.2.1 Protocol: The survey was conducted across two distinct web platforms. On the one hand, Wooclap was considered suitable to inform participants and to collect key data about their profile as it offers interactive presentation and polling tools. We chose this specific platform simply because it is made available by the institution to support didactic activities. On the other hand, the IVION platform of NAVVIS was implemented for 3D visualization purposes and to collect participants' observations in a georeferenced framework. The choice of this application is motivated by two main reasons. The first is that we had a license of IVION at our disposal since we collected part of the geometric data with the NAVVIS VLX scanner. Secondly, a system of Points Of Interest (POI) is already implemented in IVION and allows capturing and export structured metadata about POIs. IVION was considered the best solution in this case since it allowed prototype testing while limiting the needs for software development skills. Nevertheless, future research should move towards the adoption of an open-source solution that allows the development of a tailored framework without limitations or dependency on the development orientations of software manufacturers.

The data collection protocol was organized along 4 main steps (Figure 5). The first stage (I. Contextualization) included brief explanations about research context and the objectives pursued, an evaluation of participants' knowledge about the case study and a presentation of basic knowledge about the place, its evolution through time and the stakes of its conservation. During step 2 (II. Observation), after a brief initiation to the platform's interface, the stakeholder groups navigated through the 3D virtual representation of the observatory to explore the site and its constitutive components. In the third phase (III. Description), participants could describe the values they perceived in the form of Points Of Interest (POI) with structured metadata. Stakeholders were finally given the opportunity to evaluate their experience, give feedback and share specific suggestions back in wooclap (IV. Evaluation). Stage 5 (V. Interpretation) & 6 (VI. Publication) of the diagram presented below depicting the approach used for data analysis & interpretation, as well as for the representation and publication of the results. Although 60 minutes was foreseen completing the entire protocol, the survey finally lasted around 90 minutes for each group. The survey was GDPR-compliant, and it was conducted in French language. Concerning these stages, we opted for a GIS approach to evaluate the prototype's ability to generate multiple visualizations of cultural significance data through spatial analysis tools. Therefore, it was also essential for us to capture geolocation data of the identified values and of the participants' position when identifying the latter.

4.2.2 Groups and profiles of surveyed participants: To generate meaningful and interpretable representations of cultural significance data, it was necessary to target multiple user groups with various levels and types of both expertise and knowledge. According to de Sardan, the notion of interlocutors' expertise refers to the ability of this actor "to have something to say about a reference outside of their own direct experience and does not imply any value judgment on their level of knowledge" (de Sardan, 2008) (translated by authors). The polyphonic aspect of this investigation, which aims to collect viewpoints from various actors, is not intended to conduct a case study. The authors' intention was simply to enrich the database with diverse profiles and data, thereby enabling more specific analyses to be conducted.

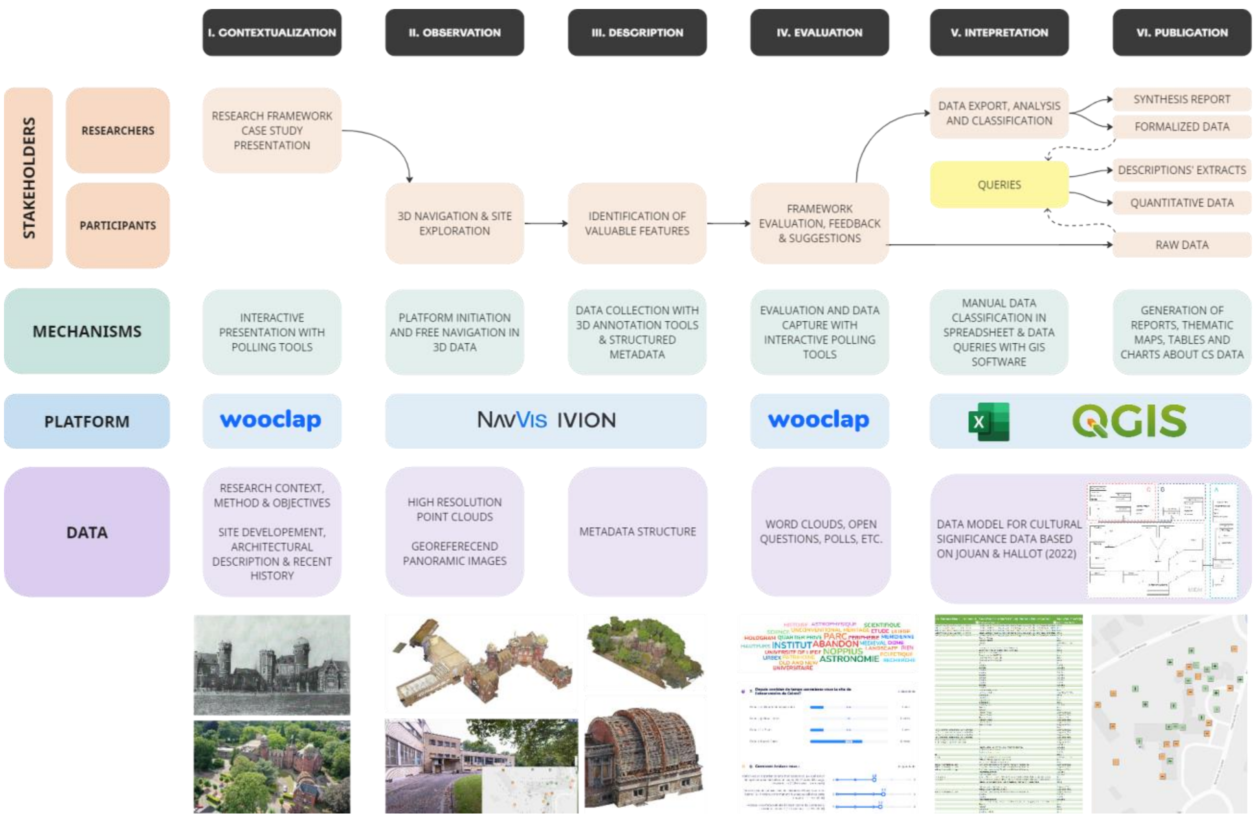

Figure 5. This chart illustrates the iterative workflow adopted for the survey of the observatory. It specifies the documentation techniques and technologies used for data acquisition as well as the applications exploited for data processing, post processing and visualization.

Two main groups were selected; a class of students pursuing an undergraduate degree in architecture (1) and a research group that consists of both academics and researchers. Several experts in the research group were involved in didactic activities in relation to the case study and had therefore a strong experience of the place. Also, although all members of the research group are related to the field of architecture, their respective domain of expertise varies from archaeology to history, construction history, archaeology, geomatics, and heritage studies. This selection ensured a wide diversity of profiles and expertise. It is not the authors’ intention to provide an extensive study about the case study significance. In this case, the issue of representativeness was only important to ensure a significant diversity of data, both regarding the participants' observations and their profile. The views expressed by the participants do not reflect the comprehensive set of values associated with the place by all stakeholders concerned by its preservation.

4.2.3 Data: In total, 18 questions were asked during the survey to collect data about the participants and their appraisal of the place. Through questions 1 and 7, participants were able to indicate what the site evoked in them both before and after the presentation, to evaluate the impact of the latter on their perception. Then, a series of questions (Q2, Q3, Q4, Q5, Q6b&c) allowed to determine their experience with the case study as well as their knowledge about its history and about the latest developments. Q6a allowed to evaluate the level of expertise of participants in the manipulation of 3D data. Question 8 allowed participants to evaluate their experience on the 3D visualization platform with a specific focus on the 3D data as well as the visualization and annotation tools available for the experiment. Through questions 9, 10 and 11, they could make suggestions about these aspects to improve the workflow. Q12 allowed us to collect information about the type of device used by the participants. Questions 13 to 17 permitted us to capture personal data related to the age, the residence, the education, and the occupation of participants. Finally, Q18 gave the opportunity to each participant to share a comment, feedback, or a suggestion about the survey.

Concerning data collected about POI, participants were simply asked to associate a POI with a tangible feature of the place while distinguishing between aspects of value, on the one hand, and disturbing elements on the other. To avoid misunderstandings about Fredheim and Khalaf's classification and misapplication of their framework, it was decided to perform the classification later manually. The data classification allowed to identify all elements related to the collected impressions and determine the category of both features of significance (form, practice & relations) and aspects of value (evidentiary, functional, sensory & associative).

5. RESULTS AND DISCUSSIONS

The collected data was exported from Wooclap and IVION respectively in .xlsx and .csv formats. Both datasets were merged using the university institutional identifier before anonymizing all data. We propose here a first analysis of the results obtained during this study. It is necessary to mention that the main contribution of this article lies in the protocol and the methodological approach implemented rather than in the formal validation of the CS identified in the following. An operational method of use of the data will be set up by a mixed group to propose tracks of valorizations and safeguard of the site.

However, we can already show several objective elements that tend to demonstrate that the principle used allows users to increase their knowledge of the site studied. Among other things, we propose in the rest of this chapter a synthesis of the different results obtained in a graphic form. Part 1 focus on a general analysis of the collected data while part 2 investigates ways to leverage the latter in a GIS environment through several spatial analysis methods and functionalities to generate new data and representations of the heritage significance of a place.

5.1 General analysis

5.1.1 Participants: Although all participants (7) to the second group (UL-FA-23-02) provided with valid answers to the complete survey, only 47 of the 57 people who took part in the first group (UL-FA-23-01) completed the entire protocol. The following charts (Figure 6) illustrate how the selection of stakeholders ensure a wide diversity of profiles with varying levels of expertise in different domains of interest for this research. In these diagrams, we focused on 5 particular aspects; the knowledge and experience of people with the place and its surroundings (1) (Site, Q2-Q6c, orange), their experience and expertise in the visualization and management of 3D data (2) (3D, Q6a, pink), their age (3) (Age range, Q13, purple), their place of residence (4) (Residence, Q14-Q15, green) and their education (5) (Education, Q16, light yellow). Lighter and darker colors in Q13 and Q16 simply indicate the proportion of people in the different ranges (darker means a higher proportion). This graph highlights the percentage range within which the average response of the relevant group is situated, except for Q4, Q13 and Q16 that respectively depict the average amount of context in which the participants visited the site (Q4), the age range in which they are situated (Q13) and the level of their highest academic degree (Q16). We evaluated stakeholders' expertise using a limited number of criteria to illustrate the diversity of profiles considered. Moreover, the relative importance or weight of each criterion and question was not assessed. The charts demonstrate that both UL-FA-23-01 and UL-FA-23-02 groups provide complementary insights across all the aspects considered. However, the analysis also reveals a lack of local participants with significant knowledge and experience of the place, which could have enriched the study's findings.

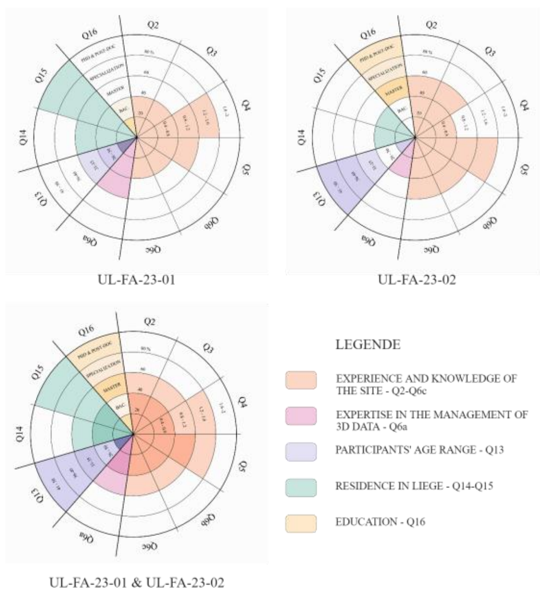

Figure 6. These diagrams illustrate the diversity and levels of expertise of group 1 (left), group 2 (right) and the combination of both (bottom left).

5.1.2 Data analysis & classification: Overall, 123 Points of Interest were created by the participants, 92 (among which 68 with a positive impact on the significance of the place) during the first session and 31 (among which 23 with a positive impact on the significance of the place) in the second one. The 92 POIs of UL-FA-23-01 were identified by 32 different participants. This lack of participation can be explained by several reasons, like the chosen format (the survey was conducted during a course) or the possibility that some students did the exercise in pairs. Also, 9 POIs were wrongly inserted, and their author could not be identified. From the 123 POIs collected, 143 aspects of value or disturbing elements could be identified.

The state-of-the-art sections highlighted the need to clearly identify the relationship between the identified values and their carrier. To do so, we proceeded to a classification of the collected data along two main stages. First, participants' observations were classified according to steps 1 & 2 of Fredheim and Khalaf's framework. This allowed to identify a category both for features of significance (form, relation, practice) and of the value aspects (associative, sensory, functional, and evidentiary). Some data were listed as “unclassifiable” (9) in the case of missing or incomplete descriptions or as “not applicable” (11) when observations were unrelated to the case study. Then, aspects of value and perturbing elements were associated with the physical entities mentioned in the corresponding descriptions. Some features of significance classified as relations were indeed associated with up to 3 tangible elements. The Industry Foundation Classes (IFC) data standard has been implemented here with a view to potential future data exploitation in a Historic Building Information Modeling (HBIM) approach. Indeed, Entities were classified following the structure of the IFC standard for spatial and building elements. Additional subcategories have been added according to the specificities of the case study. Additional classification of the collected data was achieved to distinguish observations related to the physical condition of the site as well as those referring to potential values.

5.1.3 Feedback: At the end of the survey, all stakeholders were asked to evaluate the proposed framework and give feedback about possible orientations for future developments. Overall, around 80% (83% for and 79% for UL-FA-23-02) of participants from both groups considered that the experience increased their knowledge about the place and related conservation issues. Only 53% of participants in UL-FA-23-01 considered that the experiment led them to develop new skills in the management of 3D data while this number rises to 72% for UL-FA-23-02. Both groups considered the 3D data integrated, the adopted platform for 3d visualization and its navigation functionalities, as well as the annotation system proposed suitable (average evaluation of 79% for UL-FA-23-01 and 84% for UL-FA-23-02) for the conducted survey.

In parallel, the stakeholders were asked if additional data/visualization and navigation modes/annotation functionalities would facilitate the identification of values in such a framework (Figure 7). Overall, the answers to Q9 reveals the importance of iconographic archives to inform the people involved in value assessment process about a place and its evolution through time. The need for 2d graphic documents highlighted here is logical given that both surveys were conducted in a faculty of architecture. The statistics related to Q10 highlight the interest of multiplying the navigation modes proposed in such an environment to enhance the ability of participants to explore and understand the place, regardless of their background and level of expertise in the different aspects discussed at point 5.1.1. The results of Q11 mainly shows the necessity to enable participants to associate POIs with multiple objects.

Q9 - What other type(s) of data would facilitate the value assessment process?

Answer	UL-FA-23-01	UL-FA-23-02
None	0%	0%
2D graphic documents (Plans, sections, elevations)	40%	33%
Georeferenced iconographic archives	42%	100%
3D models (mesh)	28%	0%
3D Information Model (ex.: BIM model)	30%	14%
Georeferenced ortho-images	0%	29%
Other(s)	0%	29%

Q10 - What other visualization and/or navigation mode(s) would enhance the process?

Answer	UL-FA-23-01	UL-FA-23-02
None	26%	0%
Orthographic projections	37%	71%
Immersion in Virtual Reality (VR) environment	42%	43%
Augmented Reality (AR) application	28%	43%
Visualization and navigation modes from Video games (1st person, etc.)	30%	57%
Other(s)	0%	0%

Q11 - What other annotation system would facilitate the identification of values?

Answer	UL-FA-23-01	UL-FA-23-02
None	9%	0%
Association of POIs with 3D objects	26%	29%
Association of POIs with volumes, surfaces and polylines	37%	29%
Association of POIs with several elements	44%	71%
Other(s)	2%	0%

Figure 7. This figure shows the average answers given by participants of both groups surveyed to Q9, Q10 and Q11.

5.2 Spatial-based analysis

Geolocating points of interest provides several benefits, including understanding the spatial distribution of identified values on the site (Figure 8), validating data acquisition scenarios, and informing rehabilitation policies.

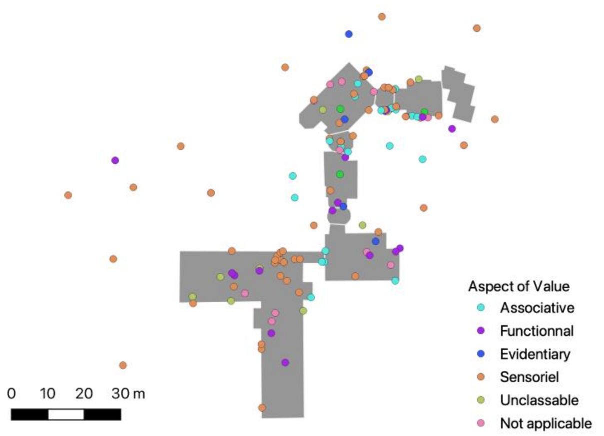

Figure 8. This illustration displays the distribution of the participants' observations on a schematic plan view of the observatory. This plan highlights the classification of the value aspects according to the framework established by Fredheim and Khalaf.

Concerning the geolocation of the points of interest, the analysis records three elements: the position of the user's point of view during the recording, the orientation vector, and the position of the point of interest itself. The first two elements allow to define if a user identifies a point of interest from a ground position or from a "fictitious" point of view compared to reality. From our perspective, a 3D navigation environment provides users with the freedom to visualize their surroundings and recognize certain values. They could identify these values just as they would by examining an aerial photograph for instance. Therefore, identification should not be restricted to points visible from ground level.

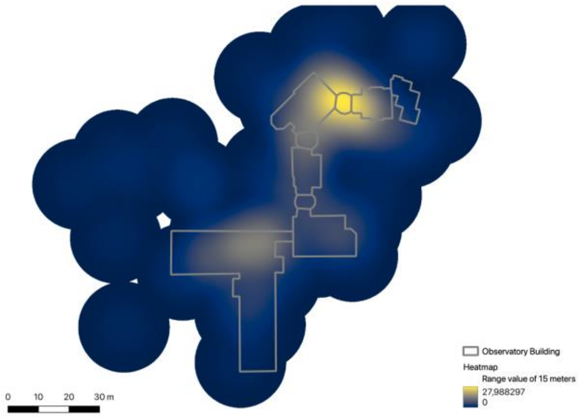

Figure 9. This figure depicts a heat map visualization of collected POIs, with a 15m radius. It shows an important concentration of values around the meridian building and the southern tour, as well as at the intersection of the Western and Southern wings of the modernist extension.

Access to user position enables spatial analysis, which can reveal the distribution of identified elements across the site. These analyses allow us to understand the distribution of the identified elements with respect to the complete site, or its constituents. We can also identify principles of spatial autocorrelation. Spatial autocorrelation is used to validate if the observed phenomenon (here the identification of a value in its category) will have a greater chance of having a neighbor that shares the same value if this neighbor is close than if it is far away (Cliff & Ord, 1984). This type of analysis is usually used to check if the observed phenomenon has a spatial component. In our case, the autocorrelation analysis would identify whether different users tend to identify the same type of values in the same areas.

The calculation shows a slight spatial autocorrelation (0,112) (Figure 10) in the values identified by each participant. This indicates that participants tend to identify values in nearby areas. In other words, we can conclude that users do not tend to vary their position to identify values in the implemented system. This can probably be explained by the limited time for the experiment and by the large number of elements to be identified. We also recall that we are dealing here with the calculation of a global spatial autocorrelation which describes a general tendency of all the participants. As can be seen in the figure below, several participants moved in and around the observatory buildings to identify values in the observatory. Based on the same approach, we can deduce that the sensory values are more localized in the 18th century and modernist wings of the building, while the associative values are more distributed on the whole site with a predominance for an identification in the park.

It seems obvious that this tool will enable project authors and site managers to confront the questionings with an objective view of various publics' perception. From this geolocalized data, many questions that architects and site managers might have about the rehabilitation of the site. can now be answered.

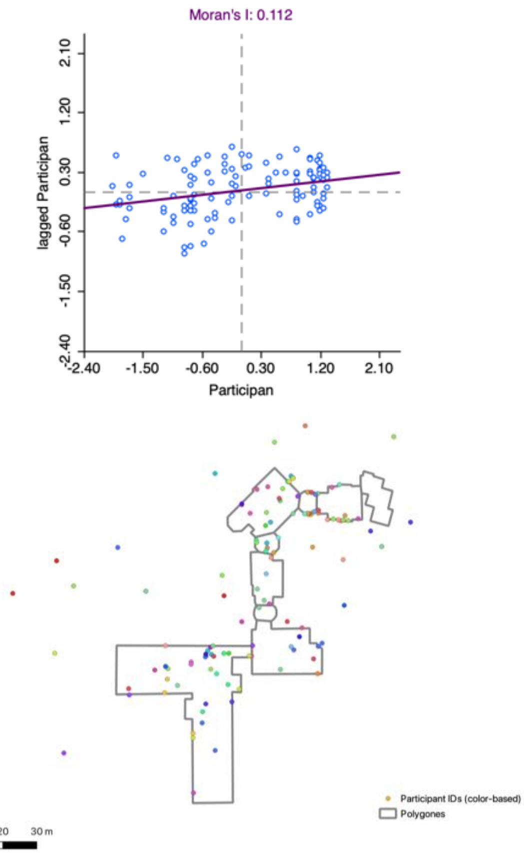

Figure 10. This diagram illustrates the results of the spatial autocorrelation calculation carried out.

From our point of view, this type of tool will also ensure a critical look at a potential project that would be geolocated on this same map. In this way, we could see if the proposed architectural response considers only one type of identified values or on the contrary if it is meant to be generalist in relation to the value aspects of the site. In any case, the objective is not to achieve a project that would only provide a solution to the values identified by a given public at a given moment, but it forces site managers and project authors to question themselves on these elements.

6. CONCLUSIONS

This study presents a novel approach to assessing the cultural significance of heritage sites by leveraging virtual representations and immersive web-based platforms. The integration of SLAM technologies and other recording techniques, such as TLS and photogrammetry, facilitates the generation of accurate and detailed 3D models of heritage sites. Our case study of the observatory of Cointe in Liège, Belgium, demonstrates the potential of this approach in capturing value judgments from multiple stakeholders through an interactive and accessible platform.

The application of this methodology supports community involvement in the conservation process, overcoming the limitations of traditional expert-centric approaches. The web-based platform and immersive virtual environment foster the participation of various social groups, enabling the collection of diverse perspectives on the cultural significance of the site. Additionally, the iterative nature of the workflow allows for continuous refinement of recording strategies as new information emerges, ensuring the adaptability and sustainability of conservation policies.

Future research should focus on the development of open-source platforms that enable customization and limit dependency on proprietary software. Furthermore, the exploration of additional case studies would help to validate and refine the proposed methodology, ultimately contributing to the development of more inclusive and sustainable conservation practices. Overall, the integration of virtual representations and web-based platforms for heritage conservation holds significant promise in enhancing the understanding and preservation of our shared cultural heritage.

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