

# USING UAV FOR CULTURAL HERITAGE: ENHANCING NEGLECTED RURAL NOBLE RESIDENCES THROUGH VIRTUAL TOURS AND GEOGRAPHIC STORYTELLING

*E. URDA<sup>1</sup>, D. A. IGNA<sup>1</sup>, E. A. KUTASI<sup>1</sup>, C. D. SECELEAN<sup>1</sup>, R. ILEA<sup>1</sup>,  
A.C. MARIAN-POTRA<sup>2,\*</sup>*

**Abstract. Using UAV for Cultural Heritage: Enhancing Neglected Rural Noble Residences Through Virtual Tours and Geographic Storytelling.**

Rural architectural heritage reflects the history and cultural identity of communities, yet the degradation of many monuments limits their visitation and valorization. Digital technologies provide alternative means of presenting and promoting this heritage. This study aimed to create a virtual tour of Bocskai Castle in Aghireșu, Cluj County, based on a 3D model obtained through UAV photogrammetry and integrated into an online spatial storytelling product. The castle, a Renaissance monument in Țara Călatei (*Kalotaszeg region*), was selected following preliminary identification of ten noble residences in the region, based on the 2015 List of Historic Monuments and available bibliographic and cartographic information. Research on the castle included field observations, a semi-structured interview with a local historian, and analysis of 80 Google Maps reviews published between 2018 and 2026. The work was completed through a UAV campaign, which generated 6,986 images, and through terrestrial photographs. Photogrammetric processing produced a georeferenced point cloud, a digital surface model, an orthophotoplan, and a textured 3D model. The materials were integrated into ArcGIS StoryMaps in a narrative with eleven sections, of which three comprise the virtual tour of the castle. The narrative presents the monument in relation to its territorial, historical, and cultural context, through architectural information, maps,

---

<sup>1</sup> Babeș-Bolyai University, Faculty of Geography, 400006, Cluj-Napoca, Romania, e-mail: [emil.urda@stud.ubbcluj.ro](mailto:emil.urda@stud.ubbcluj.ro), [denis.igna@stud.ubbcluj.ro](mailto:denis.igna@stud.ubbcluj.ro), [eduard.kutasi@stud.ubbcluj.ro](mailto:eduard.kutasi@stud.ubbcluj.ro), [constantin.secelean@stud.ubbcluj.ro](mailto:constantin.secelean@stud.ubbcluj.ro), [razvan.ilea@stud.ubbcluj.ro](mailto:razvan.ilea@stud.ubbcluj.ro)

<sup>2</sup> West University of Timișoara, Geography Department, 300223, Timișoara, România, email: [alexandra.potra@e-uvt.ro](mailto:alexandra.potra@e-uvt.ro)

photographs, and video materials. The results indicate that UAV photogrammetry can detail the current state of a degraded and partially inaccessible monument, including structural discontinuities and material losses. The virtual tour increases the visibility of the castle and facilitates free access to information, supporting the valorization and tourist promotion of rural heritage.

**Keywords:** noble residences; Bocskai Castle; UAV photogrammetry; digital heritage; spatial storytelling; virtual tour

## 1. INTRODUCTION

Historical architectural heritage, through its stylistic diversity and cultural significance, contributes to defining the identity and preserving the collective memory of the communities that created and transmitted it over time (Champion, 2015; Bonacchi, 2021). Beyond this identity function, heritage buildings are important resources for cultural tourism development and economic revitalization of local communities (Mason & Vavoula, 2021). Valorization of this potential is, however, often limited in rural areas by poor accessibility, precarious conservation status, and insufficient promotion (Timothy & Boyd, 2006; Sardaro et al., 2021). These difficulties are particularly evident in post-socialist regions, where a significant part of architectural heritage remains marginalized, despite its historical and cultural relevance (Falski & Kovářová, 2021). A representative example is provided by noble residences in Transylvania (16th–18th centuries), affected by advanced degradation (Pop & Rusu, 2015).

The integration of digital technologies into heritage documentation and promotion is a current concern of the cultural heritage sector (Bonacchi, 2021; Pop et al., 2025). The European Union designates cultural heritage digitalization as a strategic priority, supported through measures such as Commission Recommendation 2021/1970 from 10 November 2021 on a common European data space for cultural heritage, the Twin it! 3D for Europe's Culture initiative, or Digital Europe (European Commission, 2021, 2023). Digital technologies are increasingly used in the investigation of cultural heritage (Mason & Vavoula, 2021). UAV photogrammetry enables the creation of high-precision 3D models and orthophotoplans, used both for monitoring degradation and for developing virtual tours (Colomina & Molina, 2014; Chang et al., 2023). Online GIS platforms, such as ArcGIS StoryMaps, complement these products through geographic and narrative contextualization (Ulvi, 2021; Zhang et al., 2025).

The Second Chance Tourism concept supports an approach that combines 3D reproduction, immersive experience, and geographic contextualization (Bec et al., 2021). However, in Romania, the analysis of 125 museum virtual tours shows reduced integration between immersive representations, geospatial information, and narrative content (Pop et al., 2025). At national level, initiatives such as the Route of Manor Houses in Transylvania, financed through PNRR, highlight current interest in tourist promotion of Transylvanian noble heritage (Ministry of Investments and European Projects, 2024). In the case of monuments in advanced degradation, possibilities for visitation and promotion remain, however, limited. Bocskai Castle in Aghireșu (LMI Code CJ-II-m-B-07511), a Renaissance residence in Țara Călatei, represents such a case.

Accordingly, the research is guided by the following questions:

**RQ1.** To what extent does UAV photogrammetry enable the accurate documentation of degraded architectural heritage and the generation of a reality-based three-dimensional representation suitable for the virtual presentation of the monument?

**RQ2.** How can ArcGIS StoryMaps integrate photogrammetric, geographic, historical, and architectural information into an accessible digital narrative for the presentation and valorization of degraded architectural heritage?

The overall aim of this study is to develop and apply an integrated methodological workflow for the digital documentation and presentation of degraded rural architectural heritage by combining UAV photogrammetry with spatial storytelling. Using Bocskai Castle in Aghireșu, Cluj County, as a case study, the research pursues two specific objectives: (i) to document the existing architectural configuration and conservation condition of the monument through UAV-based photogrammetry and to generate a reality-based three-dimensional representation; and (ii) to integrate the resulting spatial, visual, historical, and architectural information into an ArcGIS StoryMaps environment designed for accessible virtual presentation and heritage valorization.

## **2. CONCEPTUAL FRAMEWORK**

### **2.1. From analog architectural heritage to virtual reality in heritage tourism**

In its analog form, architectural heritage is linked to the materiality of the object, its location, and direct experience of the built space (van Heur, 2010). Conventional documentation, through texts, photographs, drawings, and inventories, conserves essential information about the heritage object, but only partially reproduces its spatial and contextual complexity (Letellier, 2007; Bekele et al., 2018). Access to material heritage is conditioned by location, conservation status, and possibility of visitation, which can limit the relationship between monument and public (Fusco et al., 2024; Wang et al., 2025). The transition from analog to digital involves more than transposing information into electronic format, extending the possibilities for investigating and valorizing heritage (van Heur, 2010; Bekele et al., 2018). The resulting representations can combine images, 3D scans, and geospatial databases with audio elements, such as digital narratives and AI assistants, thereby diversifying the modes of heritage exploration (Ke et al., 2025; Orzechowski et al., 2026). The utility of these resources depends on how they are organized, contextualized, and presented (Valtolina, 2016; Mason & Vavoula, 2021; Varol & Öksüz, 2025).

Virtual reality (VR), augmented reality (AR), and mixed reality (MR) are technologies included in the Extended Reality (XR) spectrum, which describes different forms of combining the physical environment with digital content (Milgram & Kishino, 1994; Terras et al., 2021). AR is primarily associated with physical visitation, providing contextual information or visualizations of missing or reconstructed elements in relation to the existing site (Azuma, 1997; Wüest & Nebiker, 2018; Trunfio & Campana, 2020), while MR enables real-time interaction between physical and virtual components (Bec et al., 2019; Flavián et al., 2021). VR designates digitally generated environments that enable the user to explore and interact with a three-dimensional virtual space, independent of the user's physical presence at the site (Jung et al., 2015; Škola et al., 2020; Pop et al., 2025). This characteristic confers particular relevance to VR for inaccessible or vulnerable heritage, offering an alternative to direct physical access (Champion, 2015; Bec et al., 2021). In tourism, Guttentag (2010) identifies six main domains of VR application, of which three are relevant for cultural heritage: education, accessibility, and heritage conservation. From the perspective of

conservation, virtual experiences can limit access to vulnerable areas, and in tourist promotion can familiarize potential visitors with the destination and communicate the cultural value of the site (Guttentag, 2010; Bec et al., 2019).

The quality of virtual representations of heritage depends on the accuracy and level of detail of the data used for 3D reconstruction (Dellepiane et al., 2013; Ke et al., 2025). Reality-based virtual environments use data obtained directly on-site through techniques such as photogrammetry and 3D scanning (Bekele et al., 2018; Lerario & Maiellaro, 2020). Digital photogrammetry enables reconstruction of three-dimensional geometry from overlapping images and generation of products such as 3D models and georeferenced orthophotoplans (Colomina & Molina, 2014; Tong et al., 2019; Chang et al., 2023). Use of UAV technology facilitates image acquisition at high resolution and investigation of extended or difficult-to-access structures (Ulvi, 2021; Varol & Öksüz, 2025). The resulting models can serve both heritage analysis and development of interactive forms of exploration and digital communication (Bekele et al., 2018; Zhang et al., 2025).

## **2.2. Immersive storytelling for digital promotion in heritage tourism**

Immersion in VR comprises two complementary dimensions, associated with the technological characteristics of the system and the psychological experience of the user (Steuer, 1992; Hudson et al., 2019; Korżel & Łupkowski, 2023). Technological immersion refers to the measurable properties of the virtual environment, such as resolution and visual fidelity, field of view, spatial sound, performance of head-mounted display devices, and possibilities for navigation and interaction (Argyriou et al., 2020; Lerario & Maiellaro, 2020; Fan et al., 2022). These characteristics contribute to construction of the sensory experience, in which visual and audio stimuli play an important role in perceiving the virtual environment (Alyahya & McLean, 2022). The psychological dimension, associated with concepts of presence and telepresence, describes the subjective experience through which the user perceives their presence in the virtual environment (He et al., 2018; Pressgrove & Bowman, 2021; Fan et al., 2022). Although interdependent, technological immersion and psychological presence are not equivalent (Daassi & Debbabi, 2021; Korżel & Łupkowski, 2023).

Digital heritage also supports the communication and mediation of cultural content to the public (Rahaman, 2018). In this process, narrative confers

coherence on visual, spatial, and historical information, structuring representations that facilitate understanding of the cultural significance of heritage (Dogan & Kan, 2020; Barbara, 2026). Construction of narrative experience is influenced by organization of scenes, selection of points of interest, and manner of transition between them, elements that condition navigation and continuity of exploration (Incerti & Iurilli, 2015; Argyriou et al., 2020). Unlike traditional narrative, structured predominantly linearly and from a predetermined perspective, digital storytelling can transfer some control to the user, who discovers content through exploration and contextual clues (Dogan & Kan, 2020; Bonacchi, 2021; Pop et al., 2025). Immersive digital environments thus enable non-linear organization of information and selective navigation of content, offering the user the possibility of forming a personal perspective on the site, depending on the path and pace of exploration (Mason & Vavoula, 2021; Wang et al., 2025).

A specific form of immersive narrative is branching storytelling, in which the user can select different paths, scenes, or perspectives within a narrative structure defined in advance (Valtolina, 2016; Argyriou et al., 2020). Avatars and virtual guides can complement this structure by mediating interaction between user and digital environment (Almeida & Shigeo, 2002; Sylaiou et al., 2009; Machidon et al., 2018; Pop et al., 2025). The emotional dimension of experience can be supported through coordination of text, voice, ambient sound, and pace of transitions, aspects relevant to communicating heritage associated with community identity and memory (Pietroni, 2019; Mason & Vavoula, 2021). Research on VR environments for heritage indicates that association of interaction with narrative and with emotionally relevant elements can favor user engagement and understanding of cultural context (Marasco et al., 2018; Wang & Ametefe, 2026; Ioannides et al., 2026).

StoryMaps extends this narrative dimension by associating geographic information with historical, visual, and multimedia content, facilitating understanding of heritage in relation to its location and territorial context (Jeannotte, 2016; Ziku et al., 2024). Geospatial and three-dimensional products resulting from UAV analysis can complement this structure by providing spatial and visual support for representation of the site and its relationship with the territory (Ulvi, 2021; Giovannini, 2025). In this framework, the digital map transcends the function of location and becomes an environment for organizing

and exploring heritage content through relating space, information, and narrative (Ziku et al., 2024; Giovannini, 2025).

## 1. METHODOLOGY

### 3.1. Research design

The research design was constructed around the analysis of Bocskai Castle in Aghireșu, Cluj County, a monument listed in the 2015 List of Historic Monuments and classified as a noble residence. The study combined field documentation, UAV photogrammetry, and analysis of reviews published on Google Maps, to examine both the physical characteristics of the monument and the manner in which it is perceived by visitors. Research stages included site selection and contextualization, data collection, photogrammetric processing, thematic analysis of reviews, and development of the virtual tour (Fig. 1).

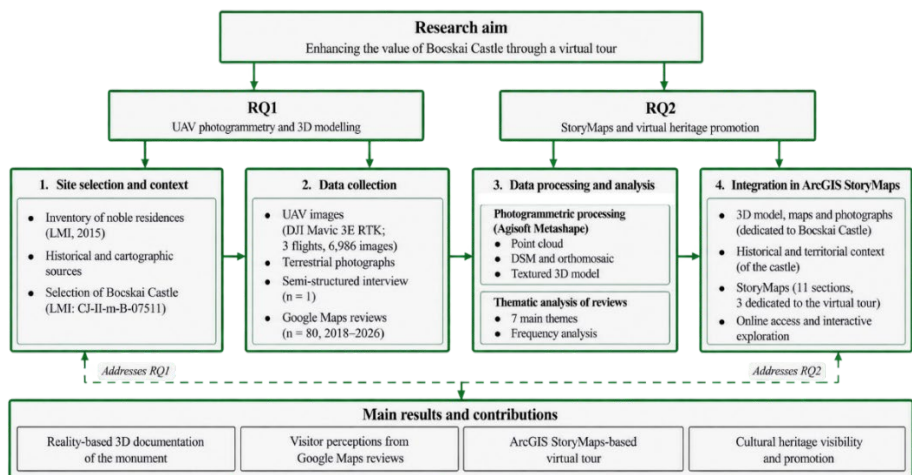


*Fig. 1. Methodology flowchart*

### 3.2. Study Area and Case Study Rationale

Țara Călatei (Kalotaszeg) is a historical-cultural and ethnographic region in northwestern Transylvania, located between Cluj-Napoca and Ciucea, primarily in the Huedin Depression and along the Căpușu and Nadășu valleys (Fig. 2). The delimitation of the region varies depending on geographic and ethnographic criteria used; specialized literature identifies between 34 and 42 localities (Nagy, 1958; Furu, 2007). The specificity of Țara Călatei is given by

the predominantly rural character of the settlements and a well-individualized ethnographic and architectural identity, expressed through traditional homesteads, vernacular architecture, folk costume, and traditional crafts, especially wood and stone processing, painted furniture, textiles, and embroidery (Furu, 2007; Eplényi, 2017). This rural landscape simultaneously preserves reminiscences of historical evolutions and former property structures that shaped Transylvania, including the presence of estates and noble residences associated with families such as Bánffy, Bocskai, Csáky, Haller, and Barcsay. Vernacular and noble heritage constitute complementary components of a cultural landscape in which local identity is expressed both through traditional living practices and forms and through the architecture and structures of former noble estates (Fig. 2) (Balogh & Fülemile, 2005; Todika, 2022).



**Fig. 2. Spatial distribution of noble residences and the location of Bocskai Castle within the Kalotaszeg region.**

The region's noble heritage presents important differences regarding conservation, use, and possibilities for tourist valorization. To characterize this

situation and position the case study within its territorial context, an inventory was created of the 10 noble residences identified in Țara Călatei, listed in the 2015 List of Historic Monuments (LMI) (Table 1). Comparison of the sites shows that some residences have been adapted for educational or commercial uses, while others are not used and are in a state of degradation or ruin. Regarding tourist valorization, the inventory indicates limited and non-uniform availability of infrastructure and resources for visitation and presentation of heritage, a situation encountered particularly in the case of unused sites.

**Table 1. Characteristics of noble residences listed as historic monuments in the Kalotaszeg region**

| No. | Noble residence                             | LMI type | Dating       | Current function                 | Conservation status           | Official website | Tourist guiding | Virtual tour | Events | Historical garden | Parking |
|-----|---------------------------------------------|----------|--------------|----------------------------------|-------------------------------|------------------|-----------------|--------------|--------|-------------------|---------|
| 1   | Conacul Gallus                              | II-m-B   | 19th century | Construction material storage    | Not rehabilitated, degraded   | -                | X               | -            | -      | -                 | -       |
| 2   | Castelul Wans-Banffy, now Gilău High School | II-a-B   | 15th century | Educational                      | Fully rehabilitated           | X                | -               | -            | -      | -                 | X       |
| 3   | Conac, now Gilău High School Dormitory      | II-m-B   | 19th century | Educational                      | Fully rehabilitated           | X                | -               | -            | X      | X                 | X       |
| 4   | Conacul Bornemisza-Matskassy                | II-m-B   | 1804         | No active function               | Ruin                          | -                | X               | -            | -      | -                 | -       |
| 5   | Casa Bogdan                                 | II-m-B   | 19th century | Commercial space at ground floor | Not rehabilitated, maintained | -                | X               | -            | -      | -                 | -       |
| 6   | Conacul Barsay                              | II-m-B   | 18th century | Educational                      | Not rehabilitated, maintained | -                | -               | -            | -      | -                 | -       |
| 7   | Conacul Banffy                              | II-m-B   | 17th century | No active function               | Ruin                          | -                | X               | -            | -      | -                 | X       |
| 8   | Casă                                        | II-m-B   | 1889–1900    | Not established                  | Not established               | -                | -               | -            | -      | -                 | -       |
| 9   | Castelul Bocskay                            | II-m-B   | 1572         | No active function               | Ruin                          | -                | -               | -            | -      | -                 | X       |
| 10  | Conacul Laszay                              | -        | -            | No active function               | Ruin                          | -                | -               | -            | -      | -                 | -       |

Source: Adapted from LMI 2015 (<https://patrimoniu.ro/ro/profiles/lista-monumentelor-istorice>)

Bocskai Castle is located in Aghireșu, northwest of Cluj-Napoca, in a historical rural context shaped by the relationship between agricultural settlements and noble estates, integrating into the network of noble residences that characterize the cultural landscape of Țara Călatei. Constructed in the second half of the sixteenth century and associated with the Bocskai family, the castle

represents a relevant example of Renaissance residential noble architecture in Transylvania, preserving elements of its historical configuration and spatial organization that permit investigation of the relationship between architecture, function, and the noble estate (Todika, 2022).

Selection of Bocskai Castle as a case study is founded on its representative character for the noble heritage of Țara Călatei, as well as the discrepancy between its historical-architectural value and current possibilities for access and valorization. The castle therefore offers a suitable case for integration of UAV data, 3D modeling, and historical information in a virtual tour designed to present the heritage and facilitate access to site information.

### **3.3. Data Acquisition**

#### ***Qualitative Data***

Information regarding noble residences included in the territorial inventory of Țara Călatei, including Bocskai Castle, was drawn from the List of Historic Monuments (LMI), published by the Ministry of Culture. Official data were used to identify and characterize the sites based on attributes such as monument code, typology, importance category, dating, and location. This information was completed through field observations and online documentation, particularly for identification of current conservation status and tourist valorization of these sites. Additional information regarding the historical evolution and significance of Bocskai Castle was obtained through a semi-structured interview with a specialist in local history. The interview addressed principal stages of the historical evolution of Aghireșu locality and the castle, changes in ownership and functionality, architectural characteristics, degradation processes, and current relationship between monument and local community. Visitor perceptions were investigated through 80 Google Maps reviews published in the period 2018–2026, collected together with associated ratings and textual content. Data were analyzed through thematic content analysis, structured around seven principal themes: sentiment expressed by visitors, state of ruins and landscape, site accessibility, aesthetic aspect of the monument, stories and descriptions associated with the place, recommendations and observations regarding the visitation experience, and non-informative reviews. For each theme, sub-themes were identified, and frequency of occurrence was quantified in the analyzed corpus.

### ***UAV Data Acquisition and Terrestrial Photography***

UAV photogrammetric survey of Boesakai Castle was conducted using a DJI Mavic 3E platform, equipped with an RTK module for positioning and direct georeferencing of images. The drone is equipped with a 20 MP RGB camera and a 1-inch CMOS sensor. The acquisition strategy combined nadir and oblique aerial images with complementary terrestrial photographs, to ensure the most complete coverage of the castle and its principal architectural elements.

UAV data acquisition was carried out through three flight missions. The first two missions were conducted at 60 m altitude above ground, in perpendicular directions, to obtain complementary coverage of the site at ensemble scale (approximately 1.9 hectares). Acquisition parameters included 80% lateral overlap and 90% longitudinal overlap, with the camera configured for acquisition of oblique images at an angle of approximately 45°. The third mission was planned based on a preliminary digital surface model (DSM) and conducted at 30 m altitude above ground, to increase the level of detail of architectural documentation of the castle ruins (approximately 40 m<sup>2</sup>). The same lateral (80%) and longitudinal (90%) overlap were maintained, and flight speed was reduced to 4.5 m/s to limit motion blur.

The UAV campaign resulted in 2,949 aerial photographs captured directly in flight and 25 minutes and 57 seconds of video material. From the video clips, 4,037 additional frames were extracted, resulting in a total of 6,986 images used in photogrammetric processing. The aerial data set was completed with high-resolution terrestrial photographs, taken manually from multiple observation points. These focused particularly on facades and architectural details less visible from the aerial perspective.

### **3.4. Photogrammetric Processing and StoryMaps Development**

The integrated set of aerial and terrestrial images was processed photogrammetrically in RealityScan 2.2, within the Unreal Engine 5.7.4 environment. The process included image loading and organization, alignment, and point cloud generation, followed by generation of a preliminary mesh for verification of reconstruction. The model was subsequently cleaned by eliminating isolated or irrelevant components, after which a high-detail mesh was generated. Final stages included UV unwrapping and texturing of the model based on photographic information. Processing was conducted using the

application's default settings, without manual modification of parameters. The final model was spatially cropped according to the analysis objective, preserving the zone corresponding to the ruins and, where necessary, a portion of adjacent space for contextualization. The 3D representation was exported in .OBJ, .STL, and .LAS formats, depending on subsequent requirements for use and visualization.

Preparation of content for ArcGIS Online StoryMaps involved organization and integration in a unified structure of multiple types of data and materials. ArcGIS Pro was used for preparation of cartographic and spatial components. These included maps regarding positioning of Țara Călatei, location of Bocskai Castle, access infrastructure, and distribution of noble residences in the study area. 3D materials were prepared for online visualization, and video representations were uploaded to YouTube and used subsequently in StoryMaps. The StoryMaps structure was organized progressively, from territorial and cultural contextualization of Țara Călatei and presentation of noble residences to focus on Bocskai Castle. Materials on location and access, historical context, architecture, and three-dimensional representation were integrated successively, each section bringing together, as appropriate, textual, cartographic, photographic, graphic, and multimedia components. The 3D virtual tour component consists of three complementary sections, presented in Section 4.3. StoryMaps also includes a methodological section on UAV data acquisition and processing, completed by representation of the point cloud resulting from photogrammetric processing.

## **4. RESULTS**

### **4.1. Historical Significance and Current Perception of Bocskai Castle**

Information obtained from the interview with the local history specialist outlines the castle's evolution in relation to changes in ownership, function, and economic profile of Aghireșu locality. Constructed between 1569 and 1572 by the Bocskai family, the castle constitutes an example of Transylvanian Renaissance architecture, characterized by a quadrilateral plan with interior courtyard, massive walls, and stone decorative elements (Fig. 3). Its initial function was as a noble residence, and the architectural configuration denotes the social status of the owner. In the context of political and military instability in Transylvania in the sixteenth century, the castle also had a protective function for

the domain population, without constituting, however, a proper military fortification.

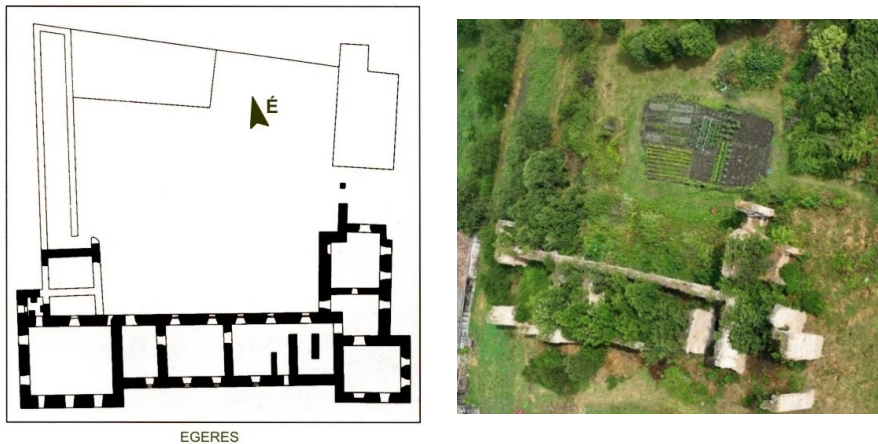


**Fig. 3. Planimetric configuration and aerial view of Bocskai Castle in Aghireșu. Left: castle plan, adapted from <https://varak.hu/sight/index/1473-Egeres-Bocskay-varkastely/>; right: author's UAV image of the surviving ruins.**

After the period in which it was owned by the Bocskai family, the castle successively passed to other noble families, including the Csáky family, and its function within the domain gradually changed.

*“The castle ceases to be a noble center, it will no longer be a noble residence, subsequently becoming a feudal domain center and a space for collecting tithes” (local historian M. M.).*

Use of cellars for wine storage and existence of a distillery indicate orientation of the complex toward economic activities of the domain. With development of the mining-industrial profile of Aghireșu, the castle was subsequently also used as residential space for mining families. Degradation of the castle occurred progressively, with loss of its functions and reduction of building use. According to the respondent, the decisive moment was the winter of 1948, when „the wooden ceiling was rotten, it was not maintained [...] and one night it collapsed” (local historian M. M.), after which the castle became impassable.

Currently, Bocskai Castle is listed in the List of Historic Monuments with code CJ-II-m-B-07511 and is registered in the National Archaeological Repertory with code 55482.07, where it is recorded with severely affected conservation

status (Fig. 4). At the level of local public administration, the monument is included in Aghireșu Commune's Development Strategy 2019–2029, in the context of measures regarding renovation and valorization of local heritage.



**Fig. 4. Current condition of the ruins of Bocskai Castle in Aghireșu. Left: aerial view of the ensemble; right: view of the surviving walls.**

Analysis is completed by examination of the 80 reviews published on Google Maps in the period 2018–2026. Based on expressed sentiment, reviews were classified into three categories: 37 positive, 22 negative, and 21 neutral. Comparison of this distribution with the frequency of themes addressed in comments shows that the overall rating does not always reflect the experiences and problems described by visitors. The most frequently encountered themes were sentiment expressed by commentators ( $n = 17$ ) and state of ruins and landscape ( $n = 13$ ), followed by accessibility ( $n = 6$ ) and aesthetic aspect of the site ( $n = 5$ ) (Table 2).

**Table 2. Frequency of themes and sub-themes identified in Google Maps reviews of Bocskai Castle**

| Theme                                | Subtheme        | Number of reviews |
|--------------------------------------|-----------------|-------------------|
| Sentiment expressed by the reviewer  | Disappointment  | 7                 |
|                                      | Dissatisfaction | 4                 |
|                                      | Sadness         | 3                 |
|                                      | Nostalgia       | 2                 |
|                                      | Hope            | 1                 |
| Condition of the ruins and landscape | Poor condition  | 13                |

|                                                                                                                                                                                                                                                  |                          |   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|---|
|                                                                                                                                                                                                                                                  | Good condition           | 0 |
| <b>Accessibility</b>                                                                                                                                                                                                                             | Low accessibility        | 4 |
|                                                                                                                                                                                                                                                  | Moderate accessibility   | 2 |
|                                                                                                                                                                                                                                                  | Good accessibility       | 0 |
| <b>Appearance</b>                                                                                                                                                                                                                                | Beautiful appearance     | 5 |
|                                                                                                                                                                                                                                                  | Ugly appearance          | 0 |
|                                                                                                                                                                                                                                                  | Mediocre appearance      | 0 |
| <b>Stories and descriptions</b>                                                                                                                                                                                                                  | Historical references    | 2 |
|                                                                                                                                                                                                                                                  | Personal impressions     | 1 |
| <b>Recommendations and observations</b>                                                                                                                                                                                                          | Positive recommendations | 1 |
|                                                                                                                                                                                                                                                  | Negative recommendations | 1 |
| <b>No informational value</b>                                                                                                                                                                                                                    | Low informational value  | 2 |
| <i>Note: The frequencies indicate the number of reviews in which each subtheme was identified. A review may contain multiple themes or subthemes, so the values are not mutually exclusive and should not add up to the total of 80 reviews.</i> |                          |   |

Analysis of sub-themes highlights that most critical references concern the state of ruins and landscape, evaluated as poor in 13 reviews, without any assessment of the state as good. Abundant vegetation, absence of maintenance interventions, and building degradation are illustrated through observations such as 'The location is not maintained, weeds are abundant and access is difficult'. The negative character of these evaluations is also reflected in the affective sub-themes, with disappointment in 7 reviews, dissatisfaction in 4, and sadness in 3.

Accessibility is evaluated as poor in 4 reviews and moderate in 2, without any positive evaluation. Comments particularly indicate lack of signage and difficulty navigating the path to the ruins. One review mentions that there is 'easy vehicular access nearby', but pedestrian access is hindered 'both by lack of an indicator and by abundant vegetation'. Access to the vicinity of the site therefore differs from access to the monument itself. Despite these evaluations, the aesthetic and historical value of the ruins remains present in visitors' perception. The sub-theme regarding beautiful appearance of the site appears in 5 reviews. The castle is described as 'a majestic and beautiful Renaissance building'.

Taken together, the interview and the review analysis reveal a contrast between the historical and architectural significance of Bocskai Castle and current conservation and visitation conditions.

#### ***4.2. Reality-Based Digital Reconstruction of Bocskai Castle***

Processing of the set of 6,986 images generated a series of complementary digital products used for investigating and representing Bocskai Castle. The processing workflow included generation of the point cloud, digital surface model (DSM), orthophotoplan, and textured three-dimensional representation.

The point cloud constituted the three-dimensional geometric foundation of the research, bringing together points with three-dimensional coordinates resulting from photogrammetric processing. With estimated precision of approximately 2–3 cm, it preserved the spatial distribution of built elements, terrain, and other surfaces recorded during acquisition (Fig. 5).



***Fig. 5. Georeferenced point cloud of Bocskai Castle generated from the UAV photogrammetric dataset.***

The digital surface model (DSM) rendered the altitudinal configuration of the site at moment of data acquisition, including relief, built structure, and vegetation. This enabled examination of the relationship between Bocskai Castle and immediate topography. Within the analysis, the DSM was also used to identify areas requiring completion of photogrammetric coverage before the third flight mission.

The orthophotoplan provided a georeferenced two-dimensional representation of investigated surfaces, obtained through geometric correction of images. With average resolution of approximately 2 cm/pixel, this enabled examination of visible details of construction in a plane related to its actual spatial position. Could be identified fragmentation of masonry, chromatic variations and materials of surfaces, zones affected by erosion, and the relationship between built structure and vegetation partially covering the complex.

Based on photogrammetric data, a three-dimensional mesh was generated, composed of a network of polygons through which the form and volumetry of the conserved components of Bocskai Castle are represented (Fig. 6). Unlike the point cloud, in which geometric information is preserved in the form of discrete points, the mesh constituted a continuous three-dimensional surface of the castle structure. It preserved structural discontinuities, gaps, and material losses existing at moment of UAV survey, without completing missing elements.

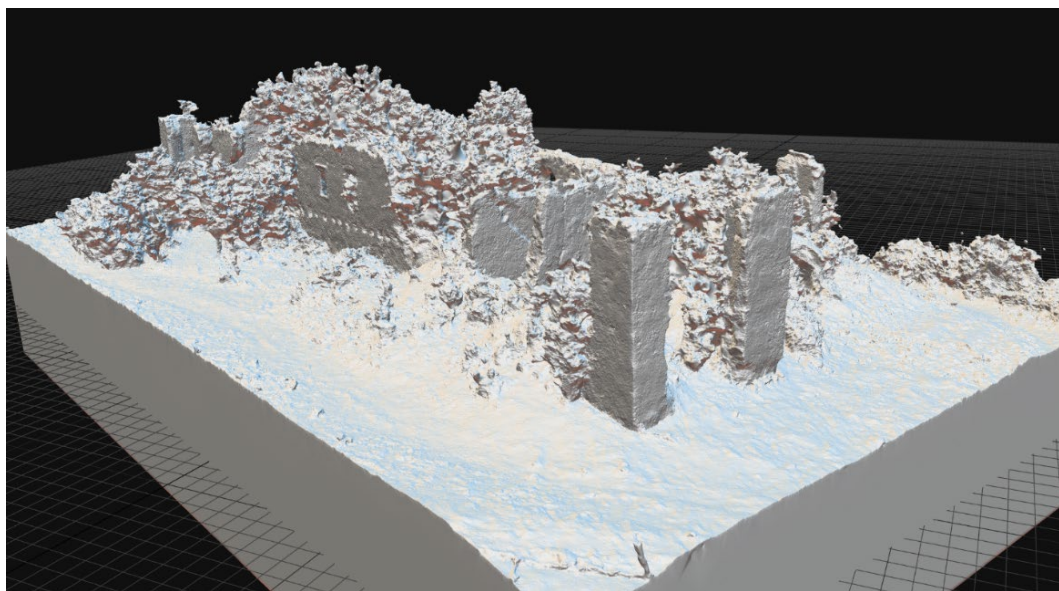


***Fig. 6. Triangulated mesh generated from the photogrammetric reconstruction of Bocskai Castle***

For application of photographic textures, the three-dimensional geometry was prepared through UV mapping, a process through which the mesh surface

was unfolded in a two-dimensional plane and correlated with images used for texturing (Fig. 7). This stage ensured correlation of reconstructed geometry with photographic images used for generation of the final model.

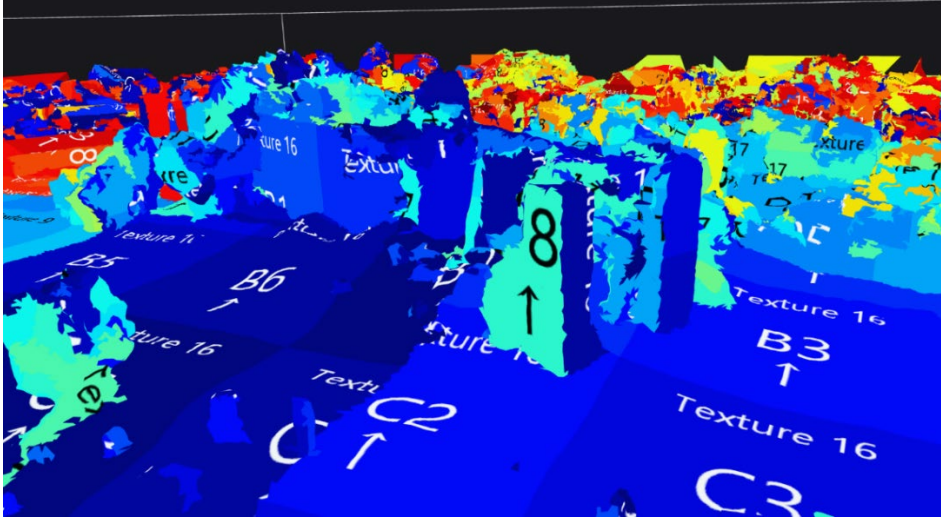


*Fig. 7. UV unwrap generated for texture mapping of the reconstructed surface.*



*Fig. 8. Final textured three-dimensional representation of Bocskai Castle derived from UAV photogrammetry*

The three-dimensional model was generated through association of photogrammetric geometry with photographic information, with the aim of rendering the physical configuration of the monument at the moment of data acquisition. It preserved degradations, discontinuities, and material losses, without completing or reconstructing missing components (Fig. 8). The resulting model subsequently formed the basis for creation of video sequences integrated in spatial storytelling.

#### 4.3. Spatial Storytelling for Virtual Exploration of Bocskai Castle

Research results were integrated, through the ArcGIS StoryMaps platform, into a digital narrative that begins with the territorial context and noble heritage of Țara Călatei and leads toward virtual exploration of the case study of Bocskai Castle (available at: <https://arcg.is/1jHqni2>). Titled From ruins to digital stories: Bocskai Castle, a landmark of noble heritage in Țara Călatei, the StoryMaps integrates textual content, maps, historical images, photographs taken during documentation, photogrammetric products, and video materials (Fig. 9).

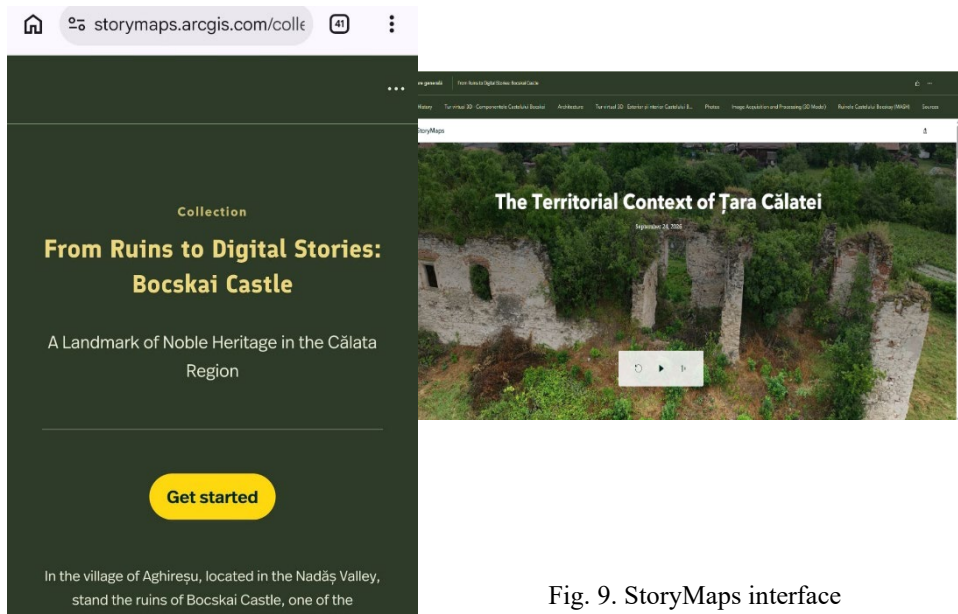


Fig. 9. StoryMaps interface

The narrative pathway is structured in eleven sections. The first of these are dedicated to the territorial and cultural context of Țara Călatei through presentation of landmarks defining the region's specificity. Location, relief

characteristics, and predominantly rural character are associated with elements of ethnographic and architectural heritage, such as traditional homesteads and buildings associated with former noble estates.

Subsequently, noble residences identified in the region are presented through a map highlighting their spatial distribution and a comparative inventory. The narrative sequence synthesizes information regarding typology of monuments, construction period, current functionality, conservation status, and existence of resources for visitation. This component positions Bocskai Castle within the context of noble heritage of Țara Călatei and permits comparison of its situation with that of other residences, particularly from perspective of conservation, use, and valorization.

The narrative for the case study begins with the location of Bocskai Castle in relation to the region, county, and Aghireșu locality, continuing with presentation of historical evolution and architectural characteristics of the monument. Bibliographic information is completed with fragments from the interview conducted with a specialist in local history, referring to evolution of property, change of functions, and castle degradation.

Virtual exploration of Bocskai Castle is structured in three successive sections, based on video renderings generated from the reality-based three-dimensional representation (Fig. 10). The first section, 3D Rendering: Aerial view of Bocskai Castle and surroundings, provides a comprehensive perspective on building configuration, its location in the local context, and access to the castle. The second section, 3D Virtual Tour: Castle components, presents the three-dimensional model of the complex from exterior perspective, highlighting its principal components, such as the main building, southeastern bastion, southwestern bastion, and interior courtyard. The third section, 3D Virtual Tour: Exterior and interior of the castle in detail, continues exploration at closer range, with emphasis on architectural details of the construction. The sequence reflects elements such as entrances, windows, and frames, alongside other particularities of conserved structure, identified through explanatory labels.

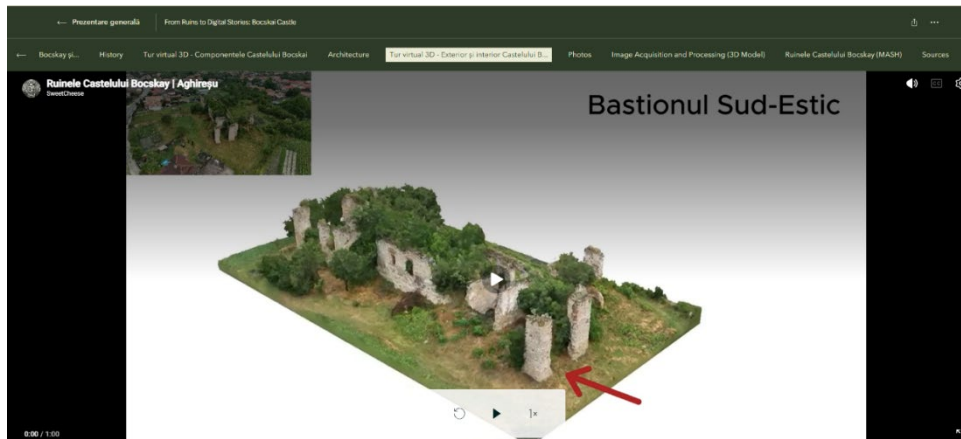


*Fig. 10. StoryMaps 3D virtual tour sections*

The story maps continues with a photo gallery with images of Bocskai Castle, inserted with role of illustrating principal visible characteristics of the structure, such as masonry, materials, degradations, and conserved architectural fragments.

After the sections dedicated to presentation and exploration of the castle, StoryMaps introduces the methodological component, dedicated to UAV data acquisition and processing. This is followed by the 3D Point Cloud: Structural study component, which integrates a video published on YouTube showing the points resulting from photogrammetric processing.

Combined in a single digital pathway, these components make StoryMaps function as support for monument presentation and as an instrument for promotion and valorization of noble heritage from Țara Călatei and dissemination of research results.

## 5. DISCUSSION

The results align with research using UAV photogrammetry and reality-based technologies in study of cultural heritage, where three-dimensional representations based on empirical data are used for analysis, conservation, and valorization of historical monuments (Bekele et al., 2018; Ulvi, 2021; Ke et al., 2025). Literature in the field of virtual heritage differentiates these representations from hypothetical digital reconstructions through direct

relationship between digital model and physical characteristics of the existing structure (Dellepiane et al., 2013; Champion, 2015). The results obtained for Bocskai Castle provide an example of application of reality-based technologies to a degraded noble residence in rural environment. The three-dimensional model reproduces the conserved configuration of the monument, including visible degradations and discontinuities, without completing missing components. The research thus contributes to extending application of this approach to partially conserved and difficult-to-access structures, and the resulting model can be used as support for presentation and digital valorization of heritage.

A second contribution of the research concerns integration of reality-based representations in spatial storytelling approaches. Recent literature on digital storytelling highlights the potential of interactive narrative structures to organize information and user experience in digital environments (Mason & Vavoula, 2021; Pressgrove & Bowman, 2021; Giovannini, 2025). The study applies this perspective to degraded architectural heritage through correlation of three-dimensional representation of Bocskai Castle with geographic, historical, and architectural information. The proposed approach addresses limitations highlighted by analysis of virtual tours in Romania, where rural heritage has reduced representation, and narrative components are integrated only to limited extent (Pop et al., 2025). Spatial storytelling is thus used as an instrument for digital valorization of architectural heritage, adapted to monuments for which physical access, conservation, and integration into visitation circuits may be limited.

From a practical and managerial perspective, the results indicate uses of digital products that exceed virtual exploration of the monument. The three-dimensional model, orthophotoplan, and spatial data obtained through photogrammetric processing can support further investigations of the structure and provide useful information for conservation, rehabilitation, or cultural management projects. The România Atractivă programme, developed through the National Recovery and Resilience Plan (PNRR), includes 12 cultural routes and 275 objectives, including the Route of Manor Houses in Transylvania, dedicated to Hungarian noble residences (Ministry of Investments and European Projects, 2024). In parallel, the ePatrimoniu project, implemented by the Ministry of Culture, aims to develop a digital infrastructure for centralization, management, and accessibility of information regarding cultural heritage, including through use

of 3D digitalization technologies (<https://mfe.gov.ro/map2021/project.php?smis=320807>). The case of Bocskai Castle highlights the potential of using digital technologies for degraded rural monuments, difficult to integrate in conventional visitation circuits or short-term restoration projects. For this category of heritage, photogrammetry can contribute both to increasing public visibility and generating data usable in processes of evaluation, conservation, rehabilitation, and cultural planning.

## 6. CONCLUSIONS

This study aimed to develop and apply a methodological approach that integrates UAV photogrammetry and spatial storytelling for exploration and promotion of degraded historical architectural heritage, using Bocskai Castle in Aghireșu as a case study. The research produced a virtual tour, presented through ArcGIS StoryMaps, in which three-dimensional representation of the monument is integrated in a spatial narrative bringing together geographic, historical, and architectural information.

Data acquired through UAV enabled generation of a 3D model, an orthophotoplan, and a point cloud, usable for analysis of spatial configuration, construction characteristics, and conservation status of the monument. Results show that, even in the case of a degraded and partially inaccessible structure, UAV photogrammetry can provide spatial and visual data sufficient for investigation of the existing structure and its translation into a virtual experience (RQ1). Use of ArcGIS StoryMaps enabled valorization of these results in an openly accessible online digital product and organization in a narrative form oriented toward monument presentation (RQ2).

StoryMaps is structured in 11 sections, three of which are dedicated to the virtual tour. A separate section presents the point cloud resulting from photogrammetric processing.

The research was complemented by information obtained from the interview conducted with a local historian and from analysis of reviews published on Google Maps. These brought into discussion both the historical significance of the monument and the manner in which visitors appreciate the cultural value of the castle in relation to its current conservation status. The methodology used can be adapted to other noble residences from Țara Călatei, with adjustment of content and modes of presentation to the particularities of each site.

The research has three main limitations. First, the methodology was applied to a single case study, without the possibility of comparing results for monuments with different architectural configurations and degradation degrees. Second, the digital product was not empirically evaluated among users, so its impact on understanding of the monument, interest in heritage, and appreciation of its cultural value was not measured. Third, the level of tour interactivity is limited by the predominantly guided character of the pathway. Exploration relies on labels, pre-established sequences, and video materials integrated through YouTube, without the possibility of direct and autonomous navigation in the three-dimensional model or interactive selection of elements of interest.

Future research could extend this approach toward a larger sample of noble residences from Țara Călatei, to analyze adaptability of the methodology to different architectural contexts and conservation degrees. Subsequent development of the tour can include more interactive features and immersive technologies, such as VR and AR, as well as evaluation of how different modes of representation and contextualization influence user experience and their relationship to degraded heritage.

### **Acknowledgements**

This study was developed as part of the spatial planning field practice organised by the Centre for Regional Geography, Faculty of Geography, Babeș-Bolyai University, Cluj-Napoca, conducted between 9 March and 1 August 2026. The authors would like to express their gratitude to all students involved in the field data collection activities, as well as to the individuals and institutions that contributed to the acquisition of data and information relevant to the research topic. The authors are particularly grateful to the local historian of Aghireșu for the interview and for sharing valuable information concerning the history, cultural heritage, and development of the study area.

### **CRedit authorship contribution statement**

Emil Urda: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing - original draft; Igna D.: Methodology, Investigation, Data curation, Formal analysis, Writing - original draft;

Kutasi E.: Methodology, Investigation, Data curation, Writing - original draft; Secelean D.: Methodology, Investigation, Formal analysis, Writing - original draft; Ilea R.: Investigation, Data curation; Marian-Potra A.C.: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing - original draft, Writing - review and editing, Supervision.

### **Declaration of generative AI use**

During the preparation of this manuscript, the authors used Claude (Anthropic, Opus 5) to assist with language editing, restructuring, and translation, as well as to produce an initial proposal for structuring the thematic categories used in the analysis of the online reviews. The proposed thematic structure was subsequently verified and refined manually by the authors based on the analysis of the original online reviews and in relation to the research objectives. Claude was not used to generate research data or to make analytical or interpretive decisions. The authors reviewed and revised all AI-assisted content and assume full responsibility for the final version of the manuscript.

### **REFERENCES.**

2. Almeida, P., & Shigeo, Y. (2002). Interactive conversational character as a virtual tour guide to an online museum exhibition. In *Proceedings of the International Conference on Computers in Education* (pp. 215–216). IEEE. <https://doi.org/10.1109/CIE.2002.1185907>
3. Alyahya, M., & McLean, G. (2022). Examining tourism consumers' attitudes and the role of sensory information in virtual reality experiences of a tourist destination. *Journal of Travel Research*, 61(7), 1538–1552. <https://doi.org/10.1177/00472875211037745>
4. Argyriou, L., Economou, D., & Bouki, V. (2020). Design methodology for 360° immersive video applications: The case study of a cultural heritage virtual tour. *Personal and Ubiquitous Computing*, 24, 843–859. <https://doi.org/10.1007/s00779-020-01373-8>
5. Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments*, 6(4), 355–385. <https://doi.org/10.1162/pres.1997.6.4.355>

6. Balogh, B., & Fülemlé, Á. (2005). Társadalom, tájszerkezet, identitás Kalotaszegen: Fejezetek a regionális csoportképzés történeti folyamatairól. Akadémiai Kiadó.
7. Barbara, J. (2026). Participative Interpretation Using Interactive Digital Storytelling. In M. Ioannides, J. Martins, & L. Cantoni (Eds.), *Digital Heritage and Cultural Tourism: Memory Twins as Tools for Sustainable Engagement* (pp. 53–65). Springer. [https://doi.org/10.1007/978-3-032-22974-8\\_4](https://doi.org/10.1007/978-3-032-22974-8_4)
8. Bec, A., Moyle, B. D., Timms, K., Schaffer, V., Skavronskaya, L., & Little, C. (2019). Management of immersive heritage tourism experiences: A conceptual model. *Tourism Management*, 72, 117–120. <https://doi.org/10.1016/j.tourman.2018.10.033>
9. Bec, A., Moyle, B. D., Schaffer, V., Timms, K., Skavronskaya, L., & Little, C. (2021). Virtual reality and mixed reality for second chance tourism. *Tourism Management*, 83, Article 104256. <https://doi.org/10.1016/j.tourman.2020.104256>
10. Bekele, M. K., Pierdicca, R., Frontoni, E., Malinverni, E. S., & Gain, J. (2018). A survey of augmented, virtual, and mixed reality for cultural heritage. *ACM Journal on Computing and Cultural Heritage*, 11(2), Article 7, 1–36. <https://doi.org/10.1145/3145534>
11. Bonacchi, C. (2021). Heritage transformations. *Big Data & Society*, 8(2). <https://doi.org/10.1177/20539517211034302>
12. Champion, E. (2015). *Critical gaming: Interactive history and virtual heritage*. Routledge.
13. Chang, M., Lee, G.-B., Lee, J. H., Lee, M., & Lee, J.-H. (2023). The influence of virtual tour on urban visitor using a network approach. *Advanced Engineering Informatics*, 56, Article 102025. <https://doi.org/10.1016/j.aei.2023.102025>
14. Colomina, I., & Molina, P. (2014). Unmanned aerial systems for photogrammetry and remote sensing: A review. *ISPRS Journal of Photogrammetry and Remote Sensing*, 92, 79–97. <https://doi.org/10.1016/j.isprsjprs.2014.02.013>
15. Daassi, M., & Debbabi, S. (2021). Intention to reuse AR-based apps: The combined role of the sense of immersion, product presence and perceived realism. *Information & Management*, 58(4), Article 103453. <https://doi.org/10.1016/j.im.2021.103453>
16. Dellepiane, M., Dell’Unto, N., Callieri, M., Lindgren, S., & Scopigno, R. (2013). Archeological excavation monitoring using dense stereo matching techniques. *Journal of Cultural Heritage*, 14(3), 201–210. <https://doi.org/10.1016/j.culher.2012.01.011>

17. Dogan, E., & Kan, M. H. (2020). Bringing heritage sites to life for visitors: Towards a conceptual framework for immersive experience. *Advances in Hospitality and Tourism Research*, 8(1), 76–99. <https://doi.org/10.30519/ahtr.630783>
18. Eplényi, A. (2017). Description methods of Kalotaszeg's landscape character. *Acta Ethnographica Hungarica*, 62(1), 221–248. <https://doi.org/10.1556/022.2017.62.1.11>
19. European Commission. (2021). *Commission recommendation (EU) 2021/1970 of 10 November 2021 on a common European data space for cultural heritage*. Official Journal of the European Union.
20. European Commission. (2023). Twin it! 3D for Europe's culture. European Commission. <https://www.europeana.eu/en/exhibitions/twin-it-3d-for-europes-culture>
21. Falski, M., & Kovářová, L. (2021). Heritage and the post-socialist city: Social and cultural perspectives. *Colloquia Humanistica*, 2021(10), Article 2696. <https://doi.org/10.11649/ch.2696>
22. Fan, X., Jiang, X., & Deng, N. (2022). Immersive technology: A meta-analysis of augmented/virtual reality applications and their impact on tourism experience. *Tourism Management*, 91, Article 104534. <https://doi.org/10.1016/j.tourman.2022.104534>
23. Flavián, C., Ibáñez-Sánchez, S., & Orús, C. (2021). The influence of scent on virtual reality experiences: The role of aroma-content congruence. *Journal of Business Research*, 123, 289–301. <https://doi.org/10.1016/j.jbusres.2020.09.036>
24. Furu, Á. (2007). *Kalotaszeg népi építésze*. Kolozsvar: Gloria Kiadó. ISBN 978-973-8267-78-7.
25. Fusco, I., Lo Presti, O., Macri, G., & Venxha, M. (2024). Valorizing historical archives for the tourist promotion of a territory: A field research between Albania and Italy. *Scientific Bulletin*, 36
26. Giovannini, E. C. (2025). HeritageMaps and digital storytelling for cultural heritage: Experiencing 3D contents from digital collections to exhibit design communication. In CHNT30, (pp. 1–4). Vienna, Austria
27. Guttentag, D. A. (2010). Virtual reality: Applications and implications for tourism. *Tourism Management*, 31(5), 637–651. <https://doi.org/10.1016/j.tourman.2009.07.003>
28. He, Z., Wu, L., & Li, X. R. (2018). When art meets tech: The role of augmented reality in enhancing museum experiences and purchase intentions. *Tourism Management*, 68, 127–139. <https://doi.org/10.1016/j.tourman.2018.03.003>
29. Hudson, S., Matson-Barkat, S., Pallamin, N., & Jegou, G. (2019). With or without you? Interaction and immersion in a virtual reality experience. *Journal*

30. Incerti, M., & Iurilli, S. (2015). Schifanoia Palace in Ferrara: A virtual storytelling for its knowledge and dissemination. In *2015 Digital Heritage* (pp. 165–168). IEEE. <https://doi.org/10.1109/DigitalHeritage.2015.7419565>
31. Ioannides, M., Martins, J., & Cantoni, L. (Eds.). (2026). Digital heritage and cultural tourism: Memory twins as tools for sustainable engagement. Springer Nature Switzerland. <https://doi.org/10.1007/978-3-032-22974-8>
32. Jeannotte, M. S. (2016). Story-telling about place: Engaging citizens in cultural mapping. *City, Culture and Society*, 7(1), 35–41. <https://doi.org/10.1016/j.ccs.2015.07.004>
33. Jung, T., Chung, N., & Leue, M. C. (2015). The determinants of recommendations to use augmented reality technologies: The case of a Korean theme park. *Tourism Management*, 49, 75–86. <https://doi.org/10.1016/j.tourman.2015.02.013>
34. Ke, P., Lin, G., & Hui, Y.-F. (2025). Immersive virtual reality design for the architectural heritage of Rovigo, Italy: Digital preservation and interactive exploration based on embodied interaction. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-M-9-2025, 659–666.
35. Korżel, K., & Łupkowski, P. (2023). The phenomenon of presence in virtual reality is mistakenly equated with immersion. *Presence: Virtual and Augmented Reality*, 32. [https://doi.org/10.1162/pres\\_a\\_00404](https://doi.org/10.1162/pres_a_00404)
36. Lerario, A., & Maiellaro, N. (2020). Virtual touring for the Puglia Regional Museum Directorate. *ISPRS International Journal of Geo-Information*, 9(12), Article 741. <https://doi.org/10.3390/ijgi9120741>
37. Letellier, R. (2007). *Recording, documentation, and information management for the conservation of heritage places*. Getty Conservation Institute.
38. Machidon, O. M., Duguleana, M., & Carrozzino, M. (2018). Virtual humans in cultural heritage ICT applications: A review. *Journal of Cultural Heritage*, 33, 249–260. <https://doi.org/10.1016/j.culher.2018.01.007>
39. Marasco, A., Buonincontri, P., van Niekerk, M., Orlowski, M., & Okumus, F. (2018). Exploring the role of next-generation virtual technologies in destination marketing. *Journal of Destination Marketing & Management*, 9, 138–148. <https://doi.org/10.1016/j.jdmm.2017.12.002>
40. Mason, M., & Vavoula, G. (2021). Digital cultural heritage design practice: A conceptual framework. *The Design Journal*, 24(3), 405–424. <https://doi.org/10.1080/14606925.2021.1889738>

41. Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems*, E77-D(12), 1321–1329.
42. Ministry of Investments and European Projects. (2024). România Atractivă: National digital platform for the promotion of cultural heritage. <https://www.romania-atractiva.ro> / (accessed 5 September 2026)
43. Nagy, J. (1958). A kalotaszegi magyar népi öltözet. București: Editura de Stat pentru Literatură și Artă.
44. Orzechowski, M., Opiola, Ł., Lamata Martínez, I., Ioannides, M., Panayiotou, P. N., Dutka, Ł., Słota, R. G., & Kitowski, J. (2026). Integrated data, metadata, and paradata management system for 3D digital cultural heritage objects: Workflow automation, federated authentication, and publication. *Future Generation Computer Systems*, 174, 107964. <https://doi.org/10.1016/j.future.2025.107964>
45. Pietroni, E. (2019). Experience design, virtual reality and media hybridization for the digital communication inside museums. *Applied System Innovation*, 2(4), Article 35. <https://doi.org/10.3390/asi2040035>
46. Pop, A.-M., & Rusu, R. (2015). The role of cultural heritage in regional development: Case study: Romania. *Romanian Review of Regional Studies*, 11(1), 69–78
47. Pop, A.-M., Marian-Potra, A.-C., Hognogi, G.-G., & Someșfălean, T. (2025). Connecting virtual tours with their tourists through immersive triggers. *Current Issues in Tourism*, 28(20), 3319–3336. <https://doi.org/10.1080/13683500.2024.2392757>
48. Pressgrove, G., & Bowman, N. D. (2021). From immersion to intention? Exploring advances in prosocial storytelling. *International Journal of Nonprofit and Voluntary Sector Marketing*, 26(2), Article e1689. <https://doi.org/10.1002/nvsm.1689>
49. Rahaman, H. (2018). Digital heritage interpretation: A conceptual framework. *Digital Creativity*, 29(2–3), 208–234. <https://doi.org/10.1080/14626268.2018.1511602>
50. Sardaro, R., La Sala, P., De Pascale, G., & Faccilongo, N. (2021). The conservation of cultural heritage in rural areas: Stakeholder preferences regarding historical rural buildings in Apulia, southern Italy. *Land Use Policy*, 109, Article 105662. <https://doi.org/10.1016/j.landusepol.2021.105662>
51. Škola, F., Rizvić, S., Cozza, M., Barbieri, L., Bruno, F., Skarlatos, D., & Liarokapis, F. (2020). Virtual reality with 360-video storytelling in cultural heritage: Study of presence, engagement, and immersion. *Sensors*, 20(20), Article 5851. <https://doi.org/10.3390/s20205851>

52. Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of Communication*, 42(4), 73–93. <https://doi.org/10.1111/j.1460-2466.1992.tb00812.x>
53. Sylaiou, S., Liarokapis, F., Kotsakis, K., & Patias, P. (2009). Virtual museums, a survey and some issues for consideration. *Journal of Cultural Heritage*, 10(4), 520–528. <https://doi.org/10.1016/j.culher.2009.03.003>
54. Terras, M., Coleman, S., Drost, S., Elsdén, C., Helgason, I., Lechelt, S., Osborne, N., Panneels, I., Pegado, B., Schafer, B., Smyth, M., Thornton, P., & Speed, C. (2021). The value of mass-digitised cultural heritage content in creative contexts. *Big Data & Society*, 8(1). <https://doi.org/10.1177/20539517211006165>
55. Timothy, D. J., & Boyd, S. W. (2006). Heritage tourism in the 21st century: Valued traditions and new perspectives. *Journal of Heritage Tourism*, 1(1), 1–16. <https://doi.org/10.1080/17438730608668462>
56. Todika, R.-A. (2022). „Rebus in adversis patientia probatur”: Castelul de la Aghireșu și proprietarii acestuia de-a lungul timpului. Anuarul Institutului de Istorie „George Barițiu” din Cluj-Napoca. Series Historica, 61.
57. Tong, X., Liu, X., Chen, P., Liu, S., Luan, K., Li, H., Hong, Z., Zhou, Y., Bao, K., & Wang, J. (2019). Three-dimensional reconstruction of structural surface model of heritage bridges using UAV-based photogrammetric point clouds. *Remote Sensing*, 11(10), Article 1204. <https://doi.org/10.3390/rs11101204>
58. Trunfio, M., & Campana, S. (2020). A visitors' experience model for mixed reality in the museum. *Current Issues in Tourism*, 23(9), 1053–1058. <https://doi.org/10.1080/13683500.2019.1586847>
59. Ulvi, A. (2021). Documentation, three-dimensional (3D) modelling and visualization of cultural heritage by using unmanned aerial vehicle (UAV) photogrammetry and terrestrial laser scanners. *International Journal of Remote Sensing*, 42(6), 1994–2021. <https://doi.org/10.1080/01431161.2020.1834164>
60. Valtolina, S. (2016). A storytelling-driven framework for cultural heritage dissemination. *Data Science and Engineering*, 1, 114–123. <https://doi.org/10.1007/s41019-016-0007-z>
61. van Heur, B. (2010). From analogue to digital and back again: Institutional dynamics of heritage innovation. *International Journal of Heritage Studies*, 16(6), 405–416. <https://doi.org/10.1080/13527258.2010.510663>
62. Varol, F., & Öksüz, M. (2025). Use of advanced measurement and reality technologies in cultural heritage sites from the perspective of technology and tourism. *Current Issues in Tourism*, 28(4), 585–603. <https://doi.org/10.1080/13683500.2024.2322693>

63. Wang, H., Du, J., Li, Y., Zhang, L., & Li, X. (2025). Grand challenges in immersive technologies for cultural heritage. *International Journal of Human-Computer Interaction*, 41(21), 13682–13703. <https://doi.org/10.1080/10447318.2025.2475996>
64. Wang, Y., & Ametefe, D. S. (2026). Immersive technologies in digital museums: A systematic review of virtual and augmented reality for heritage reconstruction and visitor experience. *Presence: Virtual and Augmented Reality*, 35, 71–93. <https://doi.org/10.1162/PRES.a.413>
65. Wüest, R., & Nebiker, S. (2018). Geospatial augmented reality for the interactive exploitation of large-scale walkable orthoimage maps in museums. *Proceedings of the International Cartographic Association*, 1, Article 124. <https://doi.org/10.5194/ica-proc-1-124-2018>
66. Zhang, D., Pan, S. L., & Guo, Z. (2025). Technology affordances, actualisation and adaptation for heritage preservation: A case study of Beijing's Palace Museum. *Information Systems Journal*, 35(3), 1045–1078. <https://doi.org/10.1111/isj.12563>
67. Ziku, M., Kotis, K., Pavlogeorgatos, G., Kavakli, E., Zeeri, C., & Caridakis, G. (2024). Evaluating crowdsourcing applications with map-based storytelling capabilities in cultural heritage. *Heritage*, 7(7), 3429–3454. <https://doi.org/10.3390/heritage7070162>