9 Infrastructure

Abstract

Currently, a large variety of infrastructures are targeting 3D models. Recently, several overview reports on extant platforms and repositories [1–5] and 3D visualization frameworks and formats [6] were compiled. Infrastructures differ from services by including tools or services and facilities for operation. Particularly for 3D models, there is a main difference between such as repositories and aggregators for storing, collecting, and preserving 3D data as well as 3D viewers or virtual research environments that allow access to 3D models and research activities with them.

Guiding questions

- What are the types of infrastructures?
- What are current challenges and developments?

Basic terms

- Linked open data
- Virtual research environments
- 3D information systems

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9.1 Digital Research Tools and Services

Infrastructures differ from services and tools.

- Digital **tools** are specialized software programs to treat a specific problem [7], e.g., the creation of a 3D model or conversion of metadata.
- A digital **service** is a managed tool operated and offered to others.
- A **digital infrastructure** comprises one or several services and/or facilities necessary for operation.

Concerning tools, basically not several research **tools** exist yet in the context of 3D reconstruction of historical architecture. Only examples can be mentioned here, as a possible list of desirable tools could be extended almost indefinitely. An overview of generic types of infrastructures is in Fig. 7.5. Examples of tool types are:

- **Plan analysis** merges the partial 2D designs of a building (plan sets) in a 3D model to uncover correlations, congruencies, and divergences.
- **3D verification** of 2D building designs with regard to construction and planning logics, impact intentions, constructability, functionality; ultimately consistent thinking and analysis in 3D.
- **Data validation** software checks the consistency of 3D datasets e.g., in the context of (H)BIM or polygonal models.
- Analysis/spatialization of **3D generated images**.

Access to 3D models is needed to evaluate and assess the quality of 3D data. In 3D reconstructions, this includes highlighting the knowledge and sources on which the modeling process is based. In addition to a number of technical requirements described in the following section, this implies a need to document processes and their results and to increase the capacity for making a model logic transparent [8, 9] (→ Documentation). A recent overview of 3D information systems and user demands revealed an especially high demand for open and accessible 3D content [5, 10].

Types of Infrastructures for 3D Models

Data repositories are collections of 3D models, which are stored and provided for secondary use. Sketchfab is the most widely used 3D repository worldwide; its heritage and history section contained around 74,000 3D models as of early 2019 [11].[1]

[1] https://sketchfab.com, accessed on 1.2.2023.

Data aggregators do not store 3D models but compile databases with the intent to prepare combined datasets for data processing. As an example, Europeana is a data aggregator compiling its collection from data in national and regional libraries.[2]

3D data viewers use computer graphics to visualize and view 3D models dynamically and enable user interactions, e.g., rotation or zooming. Current viewers, e.g., Kompakkt, are browser based [12].[3]

Virtual research environments (VREs) are web-based information systems that provide a working environment for researchers, by including various tools for analysis, comparison etc. [13]. An example is Patrimonium VRE to analyze buildings arrangements of Prussian manor houses (Fig. 9.1).[4]

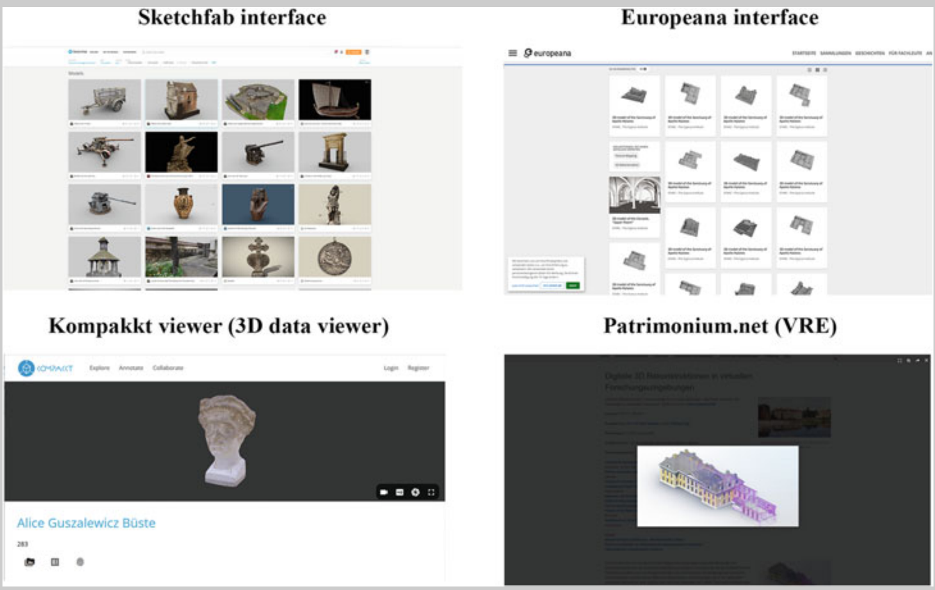

Fig. 9.1 Examples of infrastructures for 3D models

[2] https://www.europeana.eu, accessed on 1.2.2023.
[3] https://kompakkt.de/, accessed on 1.2.2023.
[4] https://www.herder-institut.de/projekte/digitale-3d-rekonstruktionen/, accessed on 1.2.2023.

9.2 Virtual Research Environments

Specifically for cultural heritage research, a large number of VREs are available—often for specific communities like archeology [14] or architectural history [15]. Depending on the group of users, there are several partially contradictory requirements: e.g., history research requires the comparability and contextualization of sources [16–19]. For architectural studies, the transparent relationship between source and representation is essential [20, 21]. For style analysis, visualization should ideally allow the identification of abstract characteristics such as ideas and systems, breaks, or deviations [22, 23]. Concerning the use and development of information, two essential modes are discernible: browsing as a self-directed search of historical sources and information [24], and location- or context-related information shared in the course of heritage presentation [25]. Finally, both research and communication approaches are usually individually adapted to a specific context. Digital tools are either tailored to individual scholarly communities or focus on laypersons and do not meet the requirements of researchers [26].

9.3 3D Information Systems

In extension to classically 2D information systems, 3D user interfaces allow users to interact with computer-generated 3D environments [27]. Especially in German-speaking countries, such systems usually focus on 2D spatial and time mapping of historical artefacts with related relation and aggregation information.

Further reading: Infrastructure Programs for 3D data

- **The European digital library Europeana** is a meta-data aggregator and a collaboration of thousands of European archives, libraries, and museums, Europeana Collections provides access to more than 50 million objects in digitized form. As part of the EU Digital Europe Program, Europeana will be empowered to contain a large number of 3D assets.
- The **German Research Data Infrastructure NFDI** is a national framework of consortia to provide domain-specific research infrastructures. Currently, three NFDI consortia provide infrastructures related to 3D data for humanities: NFDI4Culture serves the communities in art and architectural history and musicology; NFDI4Objects, archaeology; and NFDI4Memory, history.[5]

This is reflected not only in a large number of projects [28]. Perspective representations of 3D data open up a number of possibilities, especially for linking and illustrating complex

[5] https://www.nfdi.de, accessed on 1.2.2023.

historical information; virtual city and landscape models can be enriched with a variety of other site-related information [29, 30]. The linking of historical sources of different genres, their digitized data, digital research artifacts, research results, and associated meta-, para-, and context data has long been the focus of a large number of projects [31]. Specifically for history content, purposes range from humanities research and information issues to education and tourist applications [32].

9.4 Design Challenges in 3D Information Systems

The mainly technology-driven interaction forms and industry standards that have become established for 2D user interfaces [33–35] are not yet available for 3D. Research results on interaction solutions have so far gained little acceptance in the design practice of 3D applications for cultural heritage [27]. Various projects focus on gaining grounded implications for the design of 3D interfaces [36]; these design principles need to be adapted specifically for researchers in architectural history. Simple approaches based on 2D maps (e.g., Google Maps [37] or OpenStreetMap [38]) are available, also for historical images (e.g., Historypin [39]). In this spatial context, information like the distribution of images becomes visible. Deeper information becomes available in a 3D perspective: the orientation of the image and the situation of the photographer within the context of the surrounding buildings becomes clearer [40]. The user can take up the position and orientation of the camera and blend between the image and the 3D model. Combined with various historic states of a 3D model into a 4D city model, this allows comparisons between buildings.

9.5 Linked and Authority Data

Since metadata for digital objects is well established, 3D content segmentation and indexing are still unsolved these days, although this is the biggest community demand for standardization [41]. As mentioned in the previous chapter (→ Documentation), metadata provides a widely established concept for documenting processes and their results and has the capacity of making a model logic transparent [9, 42]. An important prerequisite in this respect is to identify and link elements across media [43]. Against this background, authority data is important to avoid data silos and to link enclosed projects across different media [44]. An overarching challenge is to classify 3D content information. Simple structures [45], but also complex objects such as buildings [46, 47], can be automatically segmented and assigned from datasets created by imaging processes [48, 49]. Inferences can also be made as to which parts of the image reference which parts of the 3D object geometries [50, 51]. Machine learning is playing an increasingly important role in image segmentation, object recognition [52, 53], and classification of unstructured 3D data [54–58]. A current extension is to investigate multimodal 3D retrieval and cross-validation comprising 3D data, images, and texts [59].

Summary

Infrastructures fulfill an important function in storing, sharing, and providing access to 3D models, which enables users to research and contextualize 3D data. Repositories and aggregators store data and build collections of models, while 3D viewers and VREs enable user interaction with 3D models and support specific search tasks.

Projects

- **Baureka online**: Until now, a subject-specific research data infrastructure for historical building research has been lacking. Baureka will close this gap. It is conceived as a central online research data platform for thematically international historical building research in the German-speaking area. The expert community includes architects, architectural and art historians, and monument conservators from public authorities, research institutes, foundations for building culture, and architectural and engineering offices. This heterogeneity makes internal communication and exchange across the boundaries of science and practice difficult. Baureka will promote this exchange of research data and information and significantly facilitate networked work. In the future, the platform will publish research results in an open-access format. For historical building research, this is an important step into the digital age. https://baureka.de/, accessed on 1.2.2023.
- **Monarch**: This information system specializes in the spatial digital documentation of buildings and geographical areas. It also enables the assignment of semantic information to the building structures. Thus, all information belonging to a structural object can be represented in a model-like way [60].

Key literature

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