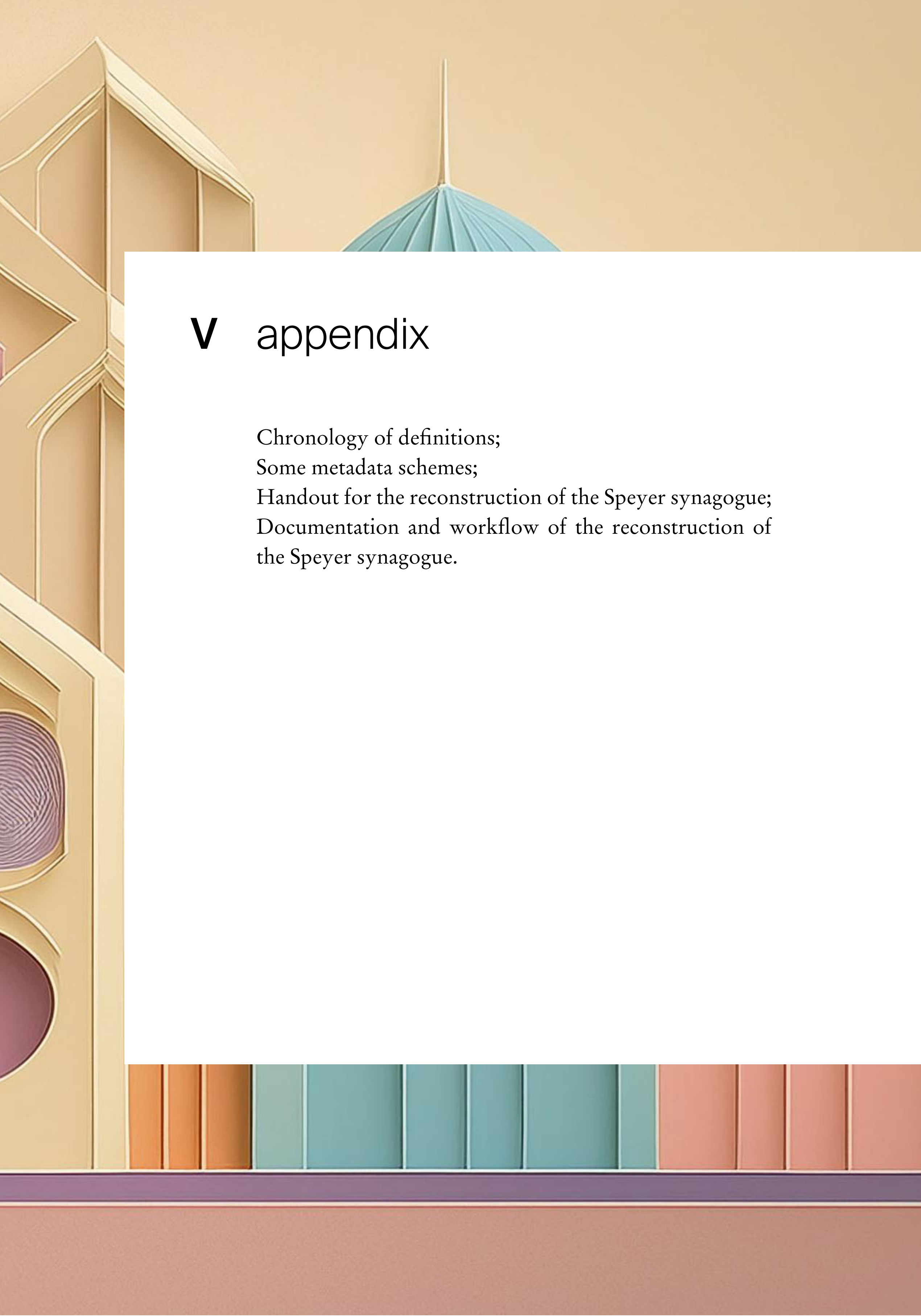

V appendix

Chronology of definitions;
Some metadata schemes;
Handout for the reconstruction of the Speyer synagogue;
Documentation and workflow of the reconstruction of the Speyer synagogue.

V

appendix

A.
APPENDIX 1. CHRONOLOGY OF DEFINITIONS

DIGITAL HERITAGE STUDIES

3D modeling In 3D computer graphics, 3D modeling is the process of developing a mathematical representation of any surface of an object (inanimate or living) in three dimensions via specialized software. The product is called a 3D model. Someone who works with 3D models may be referred to as a 3D artist or a 3D modeler. A 3D Model can also be displayed as a two-dimensional image through a process called 3D rendering or used in a computer simulation of physical phenomena. The 3D model can be physically created using 3D printing devices that form 2D layers of the model with three-dimensional material, one layer at a time. In terms of game development, 3D modeling is merely a stage in the entire development process.
3D Models may be created automatically or manually. The manual modeling process of preparing geometric data for 3D computer graphics is similar to plastic arts such as sculpting.
3D modeling software is a class of 3D computer graphics software used to produce 3D models. Individual programs of this class are called modeling applications.
<https://en.wikipedia.org/wiki/3D_modeling>

Photogrammetry is the science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena.[1]
Photogrammetry appeared in the middle of the 19th century, almost simultaneously with the appearance of photography itself. The use of photographs to create topographic maps was first proposed by the French surveyor Dominique F. Arago in about 1840.

Published in: Irene Cazzaro, Digital 3D reconstruction as a research environment in art and architecture history: Uncertainty classification and visualisation, Heidelberg: arthistoricum.net, 2025. https://doi.org/10.11588/arthistoricum.1440

The term photogrammetry was coined by the Prussian architect Albrecht Meydenbauer,[2] which appeared in his 1867 article „Die Photometrographie.“[3]

There are many variants of photogrammetry. One example is the extraction of three-dimensional measurements from two-dimensional data (i.e. images); for example, the distance between two points that lie on a plane parallel to the photographic image plane can be determined by measuring their distance on the image, if the scale of the image is known. Another is the extraction of accurate color ranges and values representing such quantities as albedo, specular reflection, metallicity, or ambient occlusion from photographs of materials for the purposes of physically based rendering.

Close-range photogrammetry refers to the collection of photography from a lesser distance than traditional aerial (or orbital) photogrammetry. Photogrammetric analysis may be applied to one photograph, or may use high-speed photography and remote sensing to detect, measure and record complex 2D and 3D motion fields by feeding measurements and imagery analysis into computational models in an attempt to successively estimate, with increasing accuracy, the actual, 3D relative motions. From its beginning with the stereoplotters used to plot contour lines on topographic maps, it now has a very wide range of uses such as sonar, radar, and lidar.

<https://en.wikipedia.org/wiki/Photogrammetry>

GIS (geographic information system) is a conceptualized framework that provides the ability to capture and analyze spatial and geographic data. GIS applications (or GIS apps) are computer-based tools that allow the user to create interactive queries (user-created searches), store and edit spatial and non-spatial data, analyze spatial information output, and visually share the results of these operations by presenting them as maps. [1][2][3]

Geographic information science (or, GIScience)—the scientific study of geographic concepts, applications, and systems—is commonly initialized as GIS, as well.[4]

Geographic information systems are utilized in multiple technologies, processes, techniques and methods. It is attached to various operations and numerous applications, that relate to: engineering, planning, management, transport/logistics, insurance, telecommunications, and business.[2] For this reason, GIS and location intelligence applications are at the foundation of location-enabled services, that rely on geographic analysis and visualization.

<https://en.wikipedia.org/wiki/Geographic_information_system>

Laser Scanning is the controlled deflection of laser beams, visible or invisible.[1] Scanned laser beams are used in some 3-D printers, in rapid prototyping, in machines for material processing, in laser engraving machines, in ophthalmological laser systems for the treatment of presbyopia, in confocal microscopy, in laser printers, in laser shows, in Laser TV, and in barcode scanners. […] Within the field of 3D object scanning, laser scanning (also known as lidar) combines controlled steering of laser beams with a laser rangefinder. By taking a distance measurement at every direction the scanner rapidly captures the surface shape of objects, buildings and landscapes. Construction of a full 3D model involves combining multiple surface models obtained from different viewing angles, or the admixing of other known constraints. Small objects can be placed on a revolving pedestal, in a technique akin to photogrammetry.
<https://en.wikipedia.org/wiki/Laser_scanning>

Interviews An interview is essentially a structured conversation where one participant asks questions, and the other provides answers.[1] In common parlance, the word „interview“ refers to a one-on-one conversation between an interviewer and an interviewee. The interviewer asks questions to which the interviewee responds, usually providing information. That information may be used or provided to other audiences immediately or later. This feature is common to many types of interviews – a job interview or interview with a witness to an event may have no other audience present at the time, but the answers will be later provided to others in the employment or investigative process. An interview may also transfer information in both directions.
<https://en.wikipedia.org/wiki/Interview>

Usability Testing is a technique used in user-centered interaction design to evaluate a product by testing it on users. This can be seen as an irreplaceable usability practice, since it gives direct input on how real users use the system.[1] It is more concerned with the design intuitiveness of the product and tested with users who have no prior exposure to it. Such testing is paramount to the success of an end product as a fully functioning application that creates confusion amongst its users will not last for long.[2] This is in contrast with usability inspection methods where experts use different methods to evaluate a user interface without involving users.
Usability testing focuses on measuring a human-made product‘s capacity to meet its intended purpose/s. Examples of products that commonly benefit from usability testing are food, consumer products, websites or web applications, computer interfaces, documents, and devices. Usabi-

lity testing measures the usability, or ease of use, of a specific object or set of objects, whereas general human–computer interaction studies attempt to formulate universal principles.
<https://en.wikipedia.org/wiki/Usability_testing>

Statistical analysis = related to machine learning. Statistical analysis is the collection and interpretation of data in order to uncover patterns and trends. It is a component of data analytics. Statistical analysis can be used in situations like gathering research interpretations, statistical modeling or designing surveys and studies. It can also be useful for business intelligence organizations that have to work with large data volumes.
In the context of business intelligence (BI), statistical analysis involves collecting and scrutinizing every data sample in a set of items from which samples can be drawn. A sample, in statistics, is a representative selection drawn from a total population.
The goal of statistical analysis is to identify trends.
<https://whatis.techtarget.com/definition/statistical-analysis#:~:text=Statistical%20analysis%20is%20the%20collection,or%20designing%20surveys%20and%20studies>

Computer vision is an interdisciplinary scientific field that deals with how computers can gain high-level understanding from digital images or videos. From the perspective of engineering, it seeks to understand and automate tasks that the human visual system can do.
Computer vision tasks include methods for acquiring, processing, analyzing and understanding digital images, and extraction of high-dimensional data from the real world in order to produce numerical or symbolic information, e.g. in the forms of decisions. Understanding in this context means the transformation of visual images (the input of the retina) into descriptions of the world that make sense to thought processes and can elicit appropriate action. This image understanding can be seen as the disentangling of symbolic information from image data using models constructed with the aid of geometry, physics, statistics, and learning theory.[8]
The scientific discipline of computer vision is concerned with the theory behind artificial systems that extract information from images. The image data can take many forms, such as video sequences, views from multiple cameras, multi-dimensional data from a 3D scanner, or medical scanning device. The technological discipline of computer vision seeks to apply its theories and models to the construction of computer vision systems. Sub-domains of computer vision include scene reconstruction, event detection, video tracking, object recognition, 3D pose estimation,

learning, indexing, motion estimation, visual servoing, 3D scene modeling, and image restoration.
<https://en.wikipedia.org/wiki/Computer_vision>

Surveying or land surveying is the technique, profession, art, and science of determining the terrestrial or three-dimensional positions of points and the distances and angles between them. A land surveying professional is called a land surveyor. These points are usually on the surface of the Earth, and they are often used to establish maps and boundaries for ownership, locations, such as the designed positions of structural components for construction or the surface location of subsurface features, or other purposes required by government or civil law, such as property sales.
Surveyors work with elements of geometry, trigonometry, regression analysis, physics, engineering, metrology, programming languages, and the law. They use equipment, such as total stations, robotic total stations, theodolites, GNSS receivers, retroreflectors, 3D scanners, radios, inclinometer, handheld tablets, optical and digital levels, subsurface locators, drones, GIS, and surveying software.
Surveying has been an element in the development of the human environment since the beginning of recorded history. The planning and execution of most forms of construction require it. It is also used in transport, communications, mapping, and the definition of legal boundaries for land ownership, and is an important tool for research in many other scientific disciplines.
https://en.wikipedia.org/wiki/Surveying3D Scanning is the process of analyzing a real-world object or environment to collect data on its shape and possibly its appearance (e.g. colour). The collected data can then be used to construct digital 3D models.
A 3D scanner can be based on many different technologies, each with its own limitations, advantages and costs. Many limitations in the kind of objects that can be digitised are still present. For example, optical technology may encounter many difficulties with shiny, reflective or transparent objects. For example, industrial computed tomography scanning and structured-light 3D scanners can be used to construct digital 3D models, without destructive testing.
Collected 3D data is useful for a wide variety of applications. These devices are used extensively by the entertainment industry in the production of movies and video games, including virtual reality.
Other common applications of this technology include augmented reality,[1] motion capture,[2][3] gesture recognition,[4] robotic mapping,[5] industrial design, orthotics and prosthetics,[6] reverse enginee-

ring and prototyping, quality control/inspection and the digitization of cultural artifacts.[7]
<https://en.wikipedia.org/wiki/3D_scanning>

Machine Learning (ML) is the study of computer algorithms that improve automatically through experience.[1] It is seen as a subset of artificial intelligence. Machine learning algorithms build a model based on sample data, known as „training data", in order to make predictions or decisions without being explicitly programmed to do so.[2] Machine learning algorithms are used in a wide variety of applications, such as email filtering and computer vision, where it is difficult or infeasible to develop conventional algorithms to perform the needed tasks.
A subset of machine learning is closely related to computational statistics, which focuses on making predictions using computers; but not all machine learning is statistical learning. The study of mathematical optimization delivers methods, theory and application domains to the field of machine learning. Data mining is a related field of study, focusing on exploratory data analysis through unsupervised learning.[4][5] In its application across business problems, machine learning is also referred to as predictive analytics.
<https://en.wikipedia.org/wiki/Machine_learning>

LiDAR is a method for measuring distances (ranging) by illuminating the target with laser light and measuring the time the reflection of the light takes to return to the sensor. Differences in laser return times and wavelengths can then be used to make digital 3-D representations of the target. It has terrestrial, airborne, and mobile applications.
The term lidar was originally a portmanteau of light and radar.[1][2] It is now also used as an acronym of „light detection and ranging"[3] and „laser imaging, detection, and ranging".[4][5] Lidar sometimes is called 3-D laser scanning, a special combination of a 3-D scanning and laser scanning. Lidar is commonly used to make high-resolution maps, with applications in surveying, geodesy, geomatics, archaeology, geography, geology, geomorphology, seismology, forestry, atmospheric physics,[6] laser guidance, airborne laser swath mapping (ALSM), and laser altimetry. The technology is also used in control and navigation for some autonomous cars.[7][8] <https://en.wikipedia.org/wiki/Lidar>

Remote Sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). Special cameras collect remotely sensed images, which help researchers "sense" things about the Earth. Some examples are:

- Cameras on satellites and airplanes take images of large areas on the Earth's surface, allowing us to see much more than we can see when standing on the ground.
- Sonar systems on ships can be used to create images of the ocean floor without needing to travel to the bottom of the ocean.
- Cameras on satellites can be used to make images of temperature changes in the oceans.

Some specific uses of remotely sensed images of the Earth include:

- Large forest fires can be mapped from space, allowing rangers to see a much larger area than from the ground.
- Tracking clouds to help predict the weather or watching erupting volcanoes, and help watching for dust storms.
- Tracking the growth of a city and changes in farmland or forests over several years or decades.
- Discovery and mapping of the rugged topography of the ocean floor (e.g., huge mountain ranges, deep canyons, and the "magnetic striping" on the ocean floor).

<https://www.usgs.gov/faqs/what-remote-sensing-and-what-it-used?qt-news_science_products=0#qt-news_science_products>

Simulation approximate imitation of the operation of a process or system that represents its operation over time.[1]
Simulation is used in many contexts, such as simulation of technology for performance tuning or optimizing, safety engineering, testing, training, education,[2] and video games. Often, computer experiments are used to study simulation models. Simulation is also used with scientific modelling of natural systems[2] or human systems to gain insight into their functioning,[3] as in economics. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Simulation is also used when the real system cannot be engaged, because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet built, or it may simply not exist.[4]
Key issues in simulation include the acquisition of valid sources of information about the relevant selection of key characteristics and behaviors, the use of simplifying approximations and assumptions within the simulation, and fidelity and validity of the simulation outcomes. Procedures and protocols for model verification and validation are an ongoing field of academic study, refinement, research and development in simulations

technology or practice, particularly in the work of computer simulation.
<https://en.wikipedia.org/wiki/Simulation>

Image Processing = related to computer vision. Digital image processing is the use of a digital computer to process digital images through an algorithm.[1][2] As a subcategory or field of digital signal processing, digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and distortion during processing. Since images are defined over two dimensions (perhaps more) digital image processing may be modeled in the form of multidimensional systems. The generation and development of digital image processing are mainly affected by three factors: first, the development of computers; second, the development of mathematics (especially the creation and improvement of discrete mathematics theory); third, the demand for a wide range of applications in environment, agriculture, military, industry and medical science has increased.
<https://en.wikipedia.org/wiki/Digital_image_processing>

Literature review discusses published information in a particular subject area, and sometimes information in a particular subject area within a certain time period.
A literature review can be just a simple summary of the sources, but it usually has an organizational pattern and combines both summary and synthesis. A summary is a recap of the important information of the source, but a synthesis is a re-organization, or a reshuffling, of that information. It might give a new interpretation of old material or combine new with old interpretations. Or it might trace the intellectual progression of the field, including major debates. And depending on the situation, the literature review may evaluate the sources and advise the reader on the most pertinent or relevant.
<https://writingcenter.unc.edu/tips-and-tools/literature-reviews/#:~:text=A%20literature%20review%20discusses%20published,combines%20both%20summary%20and%20synthesis>

Spatial Analysis is a type of geographical analysis which seeks to explain patterns of human behavior and its spatial expression in terms of mathematics and geometry, that is, locational analysis. Examples include nearest neighbor analysis and Thiessen polygons.
<https://researchguides.dartmouth.edu/gis/spatialanalysis#:~:text=Spatial%20analysis%20is%20a%20type,neighbor%20analysis%20and%20Thiessen%20polygons>

Field Survey is a type of field research by which archaeologists (often landscape archaeologists) search for archaeological sites and collect information about the location, distribution and organization of past human cultures across a large area (e.g. typically in excess of one hectare, and often in excess of many km2). Archaeologists conduct surveys to search for particular archaeological sites or kinds of sites, to detect patterns in the distribution of material culture over regions, to make generalizations or test hypotheses about past cultures, and to assess the risks that development projects will have adverse impacts on archaeological heritage.
<https://en.wikipedia.org/wiki/Survey_(archaeology)>

Database is an organized collection of data, generally stored and accessed electronically from a computer system. Where databases are more complex they are often developed using formal design and modeling techniques.
The database management system (DBMS) is the software that interacts with end users, applications, and the database itself to capture and analyze the data. The DBMS software additionally encompasses the core facilities provided to administer the database. The sum total of the database, the DBMS and the associated applications can be referred to as a “database system”. Often the term “database” is also used to loosely refer to any of the DBMS, the database system or an application associated with the database.
Computer scientists may classify database-management systems according to the database models that they support. Relational databases became dominant in the 1980s. These model data as rows and columns in a series of tables, and the vast majority use SQL for writing and querying data. In the 2000s, non-relational databases became popular, referred to as NoSQL because they use different query languages.
<https://en.wikipedia.org/wiki/Database>

Software Development is the process of conceiving, specifying, designing, programming, documenting, testing, and bug fixing involved in creating and maintaining applications, frameworks, or other software components. Software development is a process of writing and maintaining the source code, but in a broader sense, it includes all that is involved between the conception of the desired software through to the final manifestation of the software, sometimes in a planned and structured process.
Therefore, software development may include research, new development, prototyping, modification, reuse, re-engineering, maintenance, or

any other activities that result in software products.
<https://en.wikipedia.org/wiki/Software_development>

(archaeological) Excavation the exposure, processing and recording of archaeological remains.[1] An excavation site or “dig” is the area being studied. These locations range from one to several areas at a time during a project and can be conducted over a few weeks to several years.
Excavation involves the recovery of several types of data from a site. This data includes artifacts (portable objects made or modified by humans), features (non-portable modifications to the site itself such as post molds, burials, and hearths), ecofacts (evidence of human activity through organic remains such as animal bones, pollen, or charcoal), and archaeological context (relationships among the other types of data).[2][3][4][5]
Before excavating, the presence or absence of archaeological remains can often be suggested by, non-intrusive remote sensing, such as ground-penetrating radar.[6] Basic information about the development of the site may be drawn from this work, but to understand finer details of a site, excavation via augering can be used.
During excavation, archaeologists often use stratigraphic excavation to remove phases of the site one layer at a time. This keeps the timeline of the material remains consistent with one another.[7] This is done usually though mechanical means where artifacts can be spot dated and processed through methods such as sieving or flotation. Afterwards, digital methods are then used record the excavation process and its results. Ideally, data from the excavation should suffice to reconstruct the site completely in three-dimensional space.
<https://en.wikipedia.org/wiki/Archaeological_excavation>

Modelling
A model is an informative representation of an object, person or system. The term originally denoted the plans of a building in late 16th-century English, and derived via French and Italian ultimately from Latin modulus, a measure.
<https://en.wikipedia.org/wiki/Model>

Modeling and simulation (M&S) is the use of models (e.g., physical, mathematical, or logical representation of a system, entity, phenomenon, or process) as a basis for simulations to develop data utilized for managerial or technical decision-making.[1][2]
In the computer application of modeling and simulation a computer is used to build a mathematical model which contains key parameters of

the physical model. The mathematical model represents the physical model in virtual form, and conditions are applied that set up the experiment of interest. The simulation starts – i.e., the computer calculates the results of those conditions on the mathematical model – and outputs results in a format that is either machine- or human-readable, depending upon the implementation.
<https://en.wikipedia.org/wiki/Modeling_and_simulation>

(computer) Programming the process of designing and building an executable computer program to accomplish a specific computing result or to perform a specific task. Programming involves tasks such as: analysis, generating algorithms, profiling algorithms' accuracy and resource consumption, and the implementation of algorithms in a chosen programming language (commonly referred to as coding).[1][2] The source code of a program is written in one or more languages that are intelligible to programmers, rather than machine code, which is directly executed by the central processing unit. The purpose of programming is to find a sequence of instructions that will automate the performance of a task (which can be as complex as an operating system) on a computer, often for solving a given problem. Proficient programming thus often requires expertise in several different subjects, including knowledge of the application domain, specialized algorithms, and formal logic.
Tasks accompanying and related to programming include: testing, debugging, source code maintenance, implementation of build systems, and management of derived artifacts, such as the machine code of computer programs. These might be considered part of the programming process, but often the term software development is used for this larger process with the term programming, implementation, or coding reserved for the actual writing of code. Software engineering combines engineering techniques with software development practices. Reverse engineering is a related process used by designers, analysts and programmers to understand and re-create/re-implement.[3]:3
<https://en.wikipedia.org/wiki/Computer_programming>

User-centered design (UCD) is an iterative design process in which designers focus on the users and their needs in each phase of the design process. In UCD, design teams involve users throughout the design process via a variety of research and design techniques, to create highly usable and accessible products for them.
<https://www.interaction-design.org/literature/topics/user-centered-design#:~:text=User%2Dcentered%20design%20(UCD),and%20accessible%20products%20for%20them>

Network Analysis (NA) is a set of integrated techniques to depict relations among actors and to analyze the social structures that emerge from the recurrence of these relations. The basic assumption is that better explanations of social phenomena are yielded by analysis of the relations among entities.
<https://www.sciencedirect.com/topics/social-sciences/network-analysis#:~:text=Network%20analysis%20(NA)%20is%20a,of%20the%20relations%20among%20entities>

Topographic surveying accurate depiction of a site (property, area of land, defined boundary) which is scaled and detailed according to the spatial considerations and is the summary of the on-site data capture processes. This type of topographical survey is a detailed process which requires the insight of topological professionals to ensure the accuracy of all of the reports provided.
<https://indigosurveys.co.uk/what-is-a-topographical-survey/>

Data Modelling […] in software engineering is the process of creating a data model for an information system by applying certain formal techniques. [It] is a process used to define and analyze data requirements needed to support the business processes within the scope of corresponding information systems in organizations. Therefore, the process of data modeling involves professional data modelers working closely with business stakeholders, as well as potential users of the information system.
There are three different types of data models produced while progressing from requirements to the actual database to be used for the information system.[2] The data requirements are initially recorded as a conceptual data model which is essentially a set of technology independent specifications about the data and is used to discuss initial requirements with the business stakeholders. The conceptual model is then translated into a logical data model, which documents structures of the data that can be implemented in databases. Implementation of one conceptual data model may require multiple logical data models. The last step in data modeling is transforming the logical data model to a physical data model that organizes the data into tables, and accounts for access, performance and storage details. Data modeling defines not just data elements, but also their structures and the relationships between them.
<https://en.wikipedia.org/wiki/Data_modeling>
Archaeological fieldwork a body of scientific method for the responsible investigation and management of a limited and endangered resource
<http://www.eolss.net/sample-chapters/c04/E6-21-01-03.pdf>

Visualization any technique for creating images, diagrams, or animations to communicate a message. Visualization through visual imagery has been an effective way to communicate both abstract and concrete ideas since the dawn of humanity. Examples from history include cave paintings, Egyptian hieroglyphs, Greek geometry, and Leonardo da Vinci's revolutionary methods of technical drawing for engineering and scientific purposes.
Visualization today has ever-expanding applications in science, education, engineering (e.g., product visualization), interactive multimedia, medicine, etc. Typical of a visualization application is the field of computer graphics. The invention of computer graphics (and 3D computer graphics) may be the most important development in visualization since the invention of central perspective in the Renaissance period. The development of animation also helped advance visualization.
<https://en.wikipedia.org/wiki/Visualization_(graphics)>

Geophysics is a subject of natural science concerned with the physical processes and physical properties of the Earth and its surrounding space environment, and the use of quantitative methods for their analysis.
<https://en.wikipedia.org/wiki/Geophysics>

DIGITAL HUMANITIES

Text Analysis (TA) aims to extract machine-readable information from unstructured text in order to enable data-driven approaches towards managing content. To overcome the ambiguity of human language and achieve high accuracy for a specific domain, TA requires the development of customized text mining pipelines.
<https://www.ontotext.com/knowledgehub/fundamentals/text-analysis/#:~:text=Text%20Analysis%20is%20about%20parsing,manage%20and%20interpret%20data%20pieces>

Historical Studies connected to media studies, interdisciplinarity, digitization and processes of data modeling and information retrieval in digital humanities. <https://dhhistory.hypotheses.org/>

Data [/Text] Mining is a process of discovering patterns in large data sets involving methods at the intersection of machine learning, statistics, and database systems. Data mining is an interdisciplinary subfield of computer science and statistics with an overall goal to extract information (with intelligent methods) from a data set and transform the information into a comprehensible structure for further use.[1][2][3][4] Data mining is the analysis step of the „knowledge discovery in databases“ process, or KDD.[5] Aside from the raw analysis step, it also involves database and data management aspects, data pre-processing, model and inference considerations, interestingness metrics, complexity considerations, post-processing of discovered structures, visualization, and online updating.

<https://en.wikipedia.org/wiki/Data_mining>

Archives, Repositories, Sustainability As public investment in archiving research data grows, there has been increasing attention to the longevity or sustainability of the data repositories that curate such data. While there have been many conceptual frameworks developed and case reports of individual archives and digital repositories, there have been few empirical studies of how such archives persist over time. In this paper, we draw upon organizational studies theories to approach the issue of sustainability from an organizational perspective, focusing specifically on the organizational histories of three social science data archives (SSDA): ICPSR, UKDA, and LIS. Using a framework of organizational resilience to understand how archives perceive crisis, respond to it, and learn from experience, this article reports on an empirical study of sustainability in these long-lived SSDAs. The study draws from archival documents and interviews to examine how sustainability can and should be conceptualized as on-going processes over time and not as a quality at a single moment. Implications for research and practice in data archive sustainability are discussed. (Eschenfelder and Shankar 2016)
<https://datascience.codata.org/articles/10.5334/dsj-2017-012/print/>

Literary Studies -> see media studies

Visualization (already defined in the “digital heritage studies” section): any technique for creating images, diagrams, or animations to communicate a message. Visualization through visual imagery has been an effective way to communicate both abstract and concrete ideas since the dawn of humanity. Examples from history include cave paintings, Egyptian hieroglyphs, Greek geometry, and Leonardo da Vinci‘s revolutionary methods of technical drawing for engineering and scientific purposes.
Visualization today has ever-expanding applications in science, education, engineering (e.g., product visualization), interactive multimedia, medicine, etc. Typical of a visualization application is the field of computer

graphics. The invention of computer graphics (and 3D computer graphics) may be the most important development in visualization since the invention of central perspective in the Renaissance period. The development of animation also helped advance visualization.
<https://en.wikipedia.org/wiki/Visualization_(graphics)>

Corpora and Corpus Activities -> Corpus-assisted discourse studies, or CADS, is related historically and methodologically to the discipline of corpus linguistics. The principal endeavor of corpus-assisted discourse studies is the investigation, and comparison of features of particular discourse types, integrating into the analysis the techniques and tools developed within corpus linguistics. These include the compilation of specialised corpora and analyses of word and word-cluster frequency lists, comparative keyword lists and, above all, concordances.
A broader conceptualisation of corpus-assisted discourse studies would include any study that aims to bring together corpus linguistics and discourse analysis. Such research is often labelled as corpus-based or corpus-assisted discourse analysis, with the term CADS coined by a research group in Italy for a specific type of corpus-based discourse analysis (see the section ‚in different countries' below).
<https://en.wikipedia.org/wiki/Corpus-assisted_discourse_studies>

see also
Corpus linguistics is the study of language as expressed in corpora (samples) of „real world" text. Corpus linguistics proposes that reliable language analysis is more feasible with corpora collected in the field in its natural context („realia"), and with minimal experimental-interference.
The field of corpus linguistics features divergent views about the value of corpus annotation. These views range from John McHardy Sinclair, who advocates minimal annotation so texts speak for themselves,[1] to the Survey of English Usage team (University College, London), who advocate annotation as allowing greater linguistic understanding through rigorous recording.[2]
The text-corpus method is a digestive approach that derives a set of abstract rules that govern a natural language from texts in that language, and explores how that language relates to other languages. Originally derived manually, corpora now are automatically derived from source texts.
<https://en.wikipedia.org/wiki/Corpus_linguistics>

Interdisciplinary Cooperation -> Interdisciplinarity (or interdisciplinary studies) involves the combination of two or more academic disciplines into one activity (e.g., a research project).[1] It draws knowledge from several other fields like sociology, anthropology, psychology, economics etc. It is about creating something by thinking across boundaries. It is related to an interdiscipline or an interdisciplinary field, which is an organizational unit that crosses traditional boundaries between academic disciplines or schools of thought, as new needs and professions emerge. Large engineering teams are usually interdisciplinary, as a power station or mobile phone or other project requires the melding of several specialties. However, the term „interdisciplinary“ is sometimes confined to academic settings.

<https://en.wikipedia.org/wiki/Interdisciplinarity>

Digitization, Resource Creation and Discovery Digitization is the process of converting information into a digital (i.e. computer-readable) format. The result is the representation of an object, image, sound, document or signal (usually an analog signal) by generating a series of numbers that describe a discrete set of points or samples. The result is called digital representation or, more specifically, a digital image, for the object, and digital form, for the signal. In modern practice, the digitized data is in the form of binary numbers, which facilitate processing by digital computers and other operations, but, strictly speaking, digitizing simply means the conversion of analog source material into a numerical format; the decimal or any other number system that can be used instead.
Digitization is of crucial importance to data processing, storage and transmission, because it „allows information of all kinds in all formats to be carried with the same efficiency and also intermingled“. Though analog data is typically more stable, digital data can more easily be shared and accessed and can, in theory, be propagated indefinitely, without generation loss, provided it is migrated to new, stable formats as needed. This is why it is a favored way of preserving information for many organizations around the world.
<https://en.wikipedia.org/wiki/Digitization>

Content Analysis [see also Text Analysis, Text Mining, Data Mining, Machine Learning] is the study of documents and communication artifacts, which might be texts of various formats, pictures, audio or video. Social scientists use content analysis to examine patterns in communication in a replicable and systematic manner.[1] One of the key advantages of using content analysis to analyse social phenomena is its non-invasive nature, in contrast to simulating social experiences or collecting survey answers.

Practices and philosophies of content analysis vary between academic disciplines. They all involve systematic reading or observation of texts or artifacts which are assigned labels (sometimes called codes) to indicate the presence of interesting, meaningful pieces of content.[2][3] By systematically labeling the content of a set of texts, researchers can analyse patterns of content quantitatively using statistical methods, or use qualitative methods to analyse meanings of content within texts. Computers are increasingly used in content analysis to automate the labeling (or coding) of documents. Simple computational techniques can provide descriptive data such as word frequencies and document lengths. Machine learning classifiers can greatly increase the number of texts that can be labeled, but the scientific utility of doing so is a matter of debate. Further, numerous computer-aided text analysis (CATA) computer programs are available that analyze text for pre-determined linguistic, semantic, and psychological characteristics.
<https://en.wikipedia.org/wiki/Content_analysis>

Cultural Studies is a field of theoretically, politically, and empirically engaged cultural analysis that concentrates upon the political dynamics of contemporary culture, its historical foundations, defining traits, conflicts, and contingencies. Cultural studies researchers generally investigate how cultural practices relate to wider systems of power associated with or operating through social phenomena, such as ideology, class structures, national formations, ethnicity, sexual orientation, gender, and generation. Cultural studies views cultures not as fixed, bounded, stable, and discrete entities, but rather as constantly interacting and changing sets of practices and processes.[1] The field of cultural studies encompasses a range of theoretical and methodological perspectives and practices. Although distinct from the discipline of cultural anthropology and the interdisciplinary field of ethnic studies, cultural studies draws upon and has contributed to each of these fields.[2]
<https://en.wikipedia.org/wiki/Cultural_studies>

Knowledge Representation and reasoning (KR^2, KR&R) is the field of artificial intelligence (AI) dedicated to representing information about the world in a form that a computer system can utilize to solve complex tasks such as diagnosing a medical condition or having a dialog in a natural language.
Knowledge representation incorporates findings from psychology[1] about how humans solve problems and represent knowledge in order to design formalisms that will make complex systems easier to design and build. Knowledge representation and reasoning also incor-

porates findings from logic to automate various kinds of reasoning, such as the application of rules or the relations of sets and subsets.
Examples of knowledge representation formalisms include semantic nets, systems architecture, frames, rules, and ontologies. Examples of automated reasoning engines include inference engines, theorem provers, and classifiers.
<https://en.wikipedia.org/wiki/Knowledge_representation_and_reasoning>

Natural Language Processing (NLP) is a subfield of linguistics, computer science, and artificial intelligence concerned with the interactions between computers and human language, in particular how to program computers to process and analyze large amounts of natural language data.
Challenges in natural language processing frequently involve speech recognition, natural language understanding, and natural-language generation.
<https://en.wikipedia.org/wiki/Natural_language_processing>

Linking and Annotation Linguistic annotation is one of the core interfaces between linguistics and computational linguistics. It has also become a central interface between computational linguistics (CL) and digital humanities (DH). Texts are preprocessed and annotated, e.g. with parts of speech, for distant reading and other visualization applications, topic and network analyses, text mining and question answering for humanist research questions.
<https://anndh18.github.io/>

Interface and User Experience Design is the process of supporting user behavior through usability, usefulness, and desirability provided in the interaction with a product. User experience design encompasses traditional human–computer interaction (HCI) design and extends it by addressing all aspects of a product or service as perceived by users. Experience design (XD) is the practice of designing products, processes, services, events, omnichannel journeys, and environments with a focus placed on the quality of the user experience and culturally relevant solutions. Experience design is not driven by a single design discipline. Instead, it requires a cross-discipline perspective that considers multiple aspects of the brand/ business/ environment/ experience from product, packaging, and retail environment to the clothing and attitude of employees. Experience design seeks to develop the experience of a product, service, or event along any or all of the following dimensions:

- Duration (initiation, immersion, conclusion, and continuation)
- Intensity (reflex, habit, engagement)
- Breadth (products, services, brands, nomenclatures, channels/environment/promotion, and price)
- Interaction (passive - active - interactive)
- Triggers (all human senses, concepts, and symbols)
- Significance (meaning, status, emotion, price, and function)

<https://en.wikipedia.org/wiki/User_experience_design>

Linguistics -> see Corpus Linguistics

Networks, Relationships, Graphs -> see Knowledge Representation

Metadata (connected to data modeling) is „data that provides information about other data".
In other words, it is „data about data". Many distinct types of metadata exist, including descriptive metadata, structural metadata, administrative metadata, reference metadata and statistical metadata.
Descriptive metadata is descriptive information about a resource. It is used for discovery and identification. It includes elements such as title, abstract, author, and keywords.
Structural metadata is metadata about containers of data and indicates how compound objects are put together, for example, how pages are ordered to form chapters. It describes the types, versions, relationships and other characteristics of digital materials.
Administrative metadata is information to help manage a resource, like resource type, permissions, and when and how it was created.
Reference metadata is information about the contents and quality of statistical data.
Statistical metadata, also called process data, may describe processes that collect, process, or produce statistical data.
<https://en.wikipedia.org/wiki/Metadata>

Databases connected to data modeling (already defined in the "digital heritage studies" section): a database is an organized collection of data, generally stored and accessed electronically from a computer system. Where databases are more complex they are often developed using formal design and modeling techniques.
The database management system (DBMS) is the software that interacts with end users, applications, and the database itself to capture and analyze the data. The DBMS software additionally encompasses the core facilities provided to administer the database. The sum total of the data-

base, the DBMS and the associated applications can be referred to as a „database system". Often the term „database" is also used to loosely refer to any of the DBMS, the database system or an application associated with the database.
Computer scientists may classify database-management systems according to the database models that they support. Relational databases became dominant in the 1980s. These model data as rows and columns in a series of tables, and the vast majority use SQL for writing and querying data. In the 2000s, non-relational databases became popular, referred to as NoSQL because they use different query languages.
<https://en.wikipedia.org/wiki/Database>

Software Design and Development (already defined in the "digital heritage studies" section): is the process of conceiving, specifying, designing, programming, documenting, testing, and bug fixing involved in creating and maintaining applications, frameworks, or other software components. Software development is a process of writing and maintaining the source code, but in a broader sense, it includes all that is involved between the conception of the desired software through to the final manifestation of the software, sometimes in a planned and structured process. Therefore, software development may include research, new development, prototyping, modification, reuse, re-engineering, maintenance, or any other activities that result in software products.
<https://en.wikipedia.org/wiki/Software_development>

Digital Humanities - Pedagogy and Curriculum Academic institutions are starting to recognize the growing public interest in digital humanities research, and there is an increasing demand from students for formal training in its methods. Despite the pressure on practitioners to develop innovative courses, scholarship in this area has tended to focus on research methods, theories and results rather than critical pedagogy and the actual practice of teaching.
The essays in this collection offer a timely intervention in digital humanities scholarship, bringing together established and emerging scholars from a variety of humanities disciplines across the world. The first section offers views on the practical realities of teaching digital humanities at undergraduate and graduate levels, presenting case studies and snapshots of the authors' experiences alongside models for future courses and reflections on pedagogical successes and failures. The next section proposes strategies for teaching foundational digital humanities methods across a variety of scholarly disciplines, and the book concludes with wider debates about the place of digital humanities in the academy, from the

field's cultural assumptions and social obligations to its political visions. Digital Humanities pedagogy broadens the ways in which both scholars and practitioners can think about this emerging discipline, ensuring its ongoing development, vitality and long-term sustainability.
"Digital humanities pedagogy", Brett D. Hirsch (dir.), 2012
<https://books.openedition.org/obp/1605>

Digital Humanities – Diversity Digital humanities has grown and changed over the years; we have moved away from expecting technology to be a tool to make humanities research easier and faster into one where we are now equal partners. Our collaborative projects drive forward the research agendas of both humanists and technologists. There have been other changes too. The focus of our scholarly interest has moved away from its historical origins in text-based scholarship, although that now has many more possibilities, and we are seeing an interest in exploring culture and heritage more widely. Where the progress is slower is in our moves towards openness and inclusivity, and this is to some extent hampered by a lack of linguistic diversity. This is being addressed with specialist groups within the major DH organizations on a national and a global level. DH has grown rapidly in China, and the anglophone world could do more to engage with practitioners and potential colleagues in this new vibrant and emerging area. There are certainly Western centres that specialize, particularly in Chinese texts and historical documents, but this needs to be extended further if we are not to impose limits on the conversations, synergies and collaborations that can result (Mahony 2018).
<https://link.springer.com/article/10.1007/s40647-018-0216-0>

Audio, Video, Multimedia Multimedia is a form of communication that combines different content forms such as text, audio, images, animations, or video into a single presentation, in contrast to traditional mass media, such as printed material or audio recordings. Popular examples of multimedia include video podcasts, audio slideshows, animated shows, and movies.
Multimedia can be recorded for playback on computers, laptops, smartphones, and other electronic devices, either on demand or in real time (streaming). In the early years of multimedia, the term „rich media" was synonymous with interactive multimedia. Over time, hypermedia extensions brought multimedia to the World Wide Web.
<https://en.wikipedia.org/wiki/Multimedia>

Maps and Mapping -> see Knowledge Representation

Glam - Galleries, Libraries, Archives, Museums connected to databases refers to cultural institutions with a mission to provide access to knowledge. GLAMs collect and maintain cultural heritage materials in the public interest. As collecting institutions, GLAMs preserve and make accessible primary sources valuable for researchers.

Versions of the acronym include GLAMR, which specifies „records" management,[3] and the earlier form LAM, which did not specify „galleries" (whether seen as a subset of museums, or else potentially confused with commercial establishments where art is bought and sold).[4][5][6]

As an abbreviation, LAM has been in use since the 1990s;[7] it emerged as these institutions saw their missions overlapping, creating the need for a wider industry sector grouping. This became apparent as they placed their collections online—artworks, books, documents, and artifacts all effectively becoming „information resources." The work to get GLAM sector collections online is supported by GLAM Peak in Australia[8] and the National Digital Forum in New Zealand.[9]

Proponents of greater collaboration argue that the present convergence is actually a return to traditional unity. These institutions share epistemological links dating from the „Museum" of Alexandria and continuing through the cabinets of curiosities gathered in early modern Europe. Over time as collections expanded, they became more specialized and their housing was separated according to the form of information and kinds of users. Furthermore, during the nineteenth and twentieth centuries distinct professional societies and educational programs developed for each kind of institution.

<https://en.wikipedia.org/wiki/GLAM_(industry)>

Media Studies is a discipline and field of study that deals with the content, history, and effects of various media; in particular, the mass media. Media Studies may draw on traditions from both the social sciences and the humanities, but mostly from its core disciplines of mass communication, communication, communication sciences, and communication studies.

Researchers may also develop and employ theories and methods from disciplines including cultural studies, rhetoric (including digital rhetoric), philosophy, literary theory, psychology, political science, political economy, economics, sociology, anthropology, social theory, art history and criticism, film theory, and information theory.

<https://en.wikipedia.org/wiki/Media_studies>

Information Retrieval (IR) is the activity of obtaining information system resources that are relevant to an information need from a collection of those resources. Searches can be based on full-text or other content-based indexing. Information retrieval is the science of searching for information in a document, searching for documents themselves, and also searching for the metadata that describes data, and for databases of texts, images or sounds.
Automated information retrieval systems are used to reduce what has been called information overload. An IR system is a software system that provides access to books, journals and other documents; stores and manages those documents. Web search engines are the most visible IR applications.
<https://en.wikipedia.org/wiki/Information_retrieval>

Data Modeling (already defined in the "digital heritage studies" section): in software engineering is the process of creating a data model for an information system by applying certain formal techniques. [It] is a process used to define and analyze data requirements needed to support the business processes within the scope of corresponding information systems in organizations. Therefore, the process of data modeling involves professional data modelers working closely with business stakeholders, as well as potential users of the information system.
There are three different types of data models produced while progressing from requirements to the actual database to be used for the information system.[2] The data requirements are initially recorded as a conceptual data model which is essentially a set of technology independent specifications about the data and is used to discuss initial requirements with the business stakeholders. The conceptual model is then translated into a logical data model, which documents structures of the data that can be implemented in databases. Implementation of one conceptual data model may require multiple logical data models. The last step in data modeling is transforming the logical data model to a physical data model that organizes the data into tables, and accounts for access, performance and storage details. Data modeling defines not just data elements, but also their structures and the relationships between them.
<https://en.wikipedia.org/wiki/Data_modeling>

Semantic Web -> see Knowledge Representation
The Semantic Web is an extension of the World Wide Web through standards set by the World Wide Web Consortium (W3C). The goal of the Semantic Web is to make Internet data machine-readable.
To enable the encoding of semantics with the data, technologies such

as Resource Description Framework (RDF) and Web Ontology Language (OWL) are used. These technologies are used to formally represent metadata. For example, ontology can describe concepts, relationships between entities, and categories of things. These embedded semantics offer significant advantages such as reasoning over data and operating with heterogeneous data sources.
These standards promote common data formats and exchange protocols on the Web, fundamentally the RDF. According to the W3C, „The Semantic Web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries".The Semantic Web is therefore regarded as an integrator across different content and information applications and systems. The term was coined by Tim Berners-Lee for a web of data (or data web) that can be processed by machines—that is, one in which much of the meaning is machine-readable. While its critics have questioned its feasibility, proponents argue that applications in library and information science, industry, biology and human sciences research have already proven the validity of the original concept.
<https://en.wikipedia.org/wiki/Semantic_Web>

Ontologies -> see Knowledge Representation
In computer science and information science, an ontology encompasses a representation, formal naming and definition of the categories, properties and relations between the concepts, data and entities that substantiate one, many, or all domains of discourse. More simply, an ontology is a way of showing the properties of a subject area and how they are related, by defining a set of concepts and categories that represent the subject.
Every academic discipline or field creates ontologies to limit complexity and organize data into information and knowledge. New ontologies improve problem solving within that domain. Translating research papers within every field is a problem made easier when experts from different countries maintain a controlled vocabulary of jargon between each of their languages.
<https://en.wikipedia.org/wiki/Ontology_(information_science)>

The full definitions of the words contained in the 27 analysed papers (see **CHAPTER I**) are presented below in chronological order and divided by thematic area according to this key:

- Virtual Archaeology
- Model / Visualisation
- Documentation
- Authenticity
- Uncertainty
- Cultural Heritage

Some papers have been attributed to more than one thematic area (represented by the coloured circles on the left); the main one is indicated in the colour of the title.

Duranti (Berners-Lee 2006)

Legally authentic documents are those which bear witness on their own because of the intervention, during or after their creation, of a representative of a public authority guaranteeing their genuineness. **Diplomatically authentic** documents are those which were written according to the practice of the time and place indicated in the text, and signed with the name(s) of the person(s) competent to create them. **Historically authentic** documents are those which attest to events that actually took place or to information that is true. The three types of authenticity are totally inde- pendent of one another.

Document de Nara sur l'authenticité (1994)

French / *English* versions of the document

Conservation: comprend toutes les opérations qui visent à comprendre une œuvre, à connaître son histoire et sa signification, à assurer sa sauvegarde matérielle et, éventuellement sa restauration et sa mise en valeur. (Le patrimoine culturel comprend les monuments, les ensembles bâtis et les sites tels que les définit l'article 1 de la Convention du patrimoine mondial) / ***Conservation**: all efforts designed to understand cultural heritage, know its history and meaning, ensure its material safeguard and, as required, its presentation, restoration and enhancement.*

(Cultural heritage is understood to include monuments, groups of buildings and sites of cultural value as defined in article one of the World Heritage Convention).

Sources d'information: ensemble des sources monumentales, écrites, orales, figurées, permettant de connaître la nature, les spécificités, la signification et l'histoire d'une œuvre / ***Information sources**: all material, written, oral and figurative sources which make it possible to know the nature, specifications, meaning and history of the cultural heritage.*

Taylor and Kuyatt (1989)

The **uncertainty** of the result of a measurement generally consists of several components which, in the CIPM[1] approach, may be grouped into two categories according to the method used to estimate their numerical values:

A. those which are evaluated by statistical methods

B. those which are evaluated by other means.

In general, the result of a measurement is only an approximation or estimate of the value of the specific quantity subject to measurement, that is, the measurand, and thus the result is complete only when accompanied by a quantitative statement of its uncertainty.

Goodchild et al. (1994)

Information on validity affects the reliability of all aspects of analysis, spatial inference and reasoning. It also affects the **credibility** attached to decisions […]. The term '**validity**' encompasses concepts related to measurable validity, including, but not limited to, measurement by deductive estimates, inferential evidence, or comparison with independent sources. […] Validity can thus encompass both the accuracy of data and of the procedures applied to those data.

The term '**data quality**' encompasses more than testable elements subsumed here under validity, incorporating aspects of lineage that are often monitored or tracked in database operations. Trackable elements

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1 Comité International des Poids et Mesures (International Committee for Weights and Measures).

include chronological reporting of data collection and processing, algorithms used to process the data, and tests applied to the evaluation.

The types of validity that may be discovered or measured in geographical data most commonly include error and accuracy.

Accuracy measures the discrepancy from a modelled or an assumed value, while error measures discrepancy from the true value.

Although data validity may be measurable, data quality has been defined as a point in the three-dimensional space of data goodness, application and purpose.

Hunter and Goodchild (1994)

In the context of geographic data, it is argued there is a clear distinction between '**error**' and '**uncertainty**', since the former implies that some degree of knowledge has been attained about differences (and the reasons for their occurrence) between the results or observations and the truth to which they pertain. On the other hand, 'uncertainty' conveys the fact that it is the lack of such knowledge which is responsible for hesitancy in accepting those same results or observations without caution, and often the term 'error' is used when it would be more appropriate to use 'uncertainty'.

JCGM 100:2008 GUM 1995 with minor corrections[2]

The word "**uncertainty**" means doubt, and thus in its broadest sense "uncertainty of measurement" means doubt about the validity of the result of a measurement. Because of the lack of different words for this general concept of uncertainty and the specific quantities that provide quantitative measures of the concept, for example, the standard deviation, it is necessary to use the word "uncertainty" in these two different senses.

2 A working group of the Joint Committee for Guides in Metrology (JCGM), convened by the Bureau International des Poids et Mesures, has developed these guidelines starting from the Recommendation 1 (CI-1981) of the Comité International des Poids et Mesures (CIPM) and Recommendation INC-1 (1980) of the Working Group on the Statement of Uncertainties. "GUM" stands for "Guides for the expression of Uncertainty in Measurement".

2.2.2 In this Guide, the word "uncertainty" without adjectives refers both to the general concept of uncertainty and to any or all quantitative measures of that concept. When a specific measure is intended, appropriate adjectives are used.

NOTE The result of a measurement (after correction) can unknowably be very close to the value of the measurand (and hence have a negligible error) even though it may have a large uncertainty. Thus the uncertainty of the result of a measurement should not be confused with the remaining unknown error.

3.3.2 In practice, there are many possible sources of uncertainty in a measurement, including:

a) Incomplete definition of the measurand;

b) Imperfect realization of the definition of the measurand;

c) Nonrepresentative sampling – the sample measured may not represent the defined measurand;

d) Inadequate knowledge of the effects of environmental conditions on the measurement or imperfect measurement of environmental conditions;

e) Personal bias in reading analogue instruments;

f) Finite instrument resolution or discrimination threshold;

g) Inexact values of measurement standards and reference materials;

h) Inexact values of constants and other parameters obtained from external sources and used in the data-reduction algorithm;

i) Approximations and assumptions incorporated in the measurement method and procedure;

j) Variations in repeated observations of the measurand under apparently identical conditions.

ICOMOS Principles for the recording of monuments, groups of buildings and sites 1996

Cultural Heritage refers to monuments, groups of buildings and sites of heritage value, constituting the historic or built environment.

Recording is the capture of information which describes the physical configuration, condition and use of monuments, groups of buildings and sites, at points in time, and it is an essential part of the conservation process.

Records of monuments, groups of buildings and sites may include tangible as well as intangible evidence, and constitute a part of the documentation that can contribute to an understanding of the heritage and its related values.

Pang et al. (1995)

We define **uncertainty** to include statistical variations or spread, errors and differences, minimum-maximum range values, noisy, or missing data. This broad umbrella is intended to capture most if not all the possible types and sources of uncertainty in data. NIST [Taylor and Kuyatt 1993, author's note] has written a standards report which identifies four ways of expressing uncertainty. For the discussion in this paper, we consider three types of uncertainty: **statistical** – either given by the estimated mean and standard deviation, which can be used to calculate a confidence interval, or an actual distribution of the data; **error** – a difference, or an absolute valued error among estimates of the data, or between a known correct datum and an estimate; and **range** – an interval in which the data must exist, but which cannot be quantified into either the statistical or error definitions. Note that the term **data quality has an inverse relationship with data uncertainty** and hence can also take advantage of the techniques presented in this paper.

Smets (1996)

Imperfection, be it **imprecision** or **uncertainty**, pervades real world scenarios and must be incorporated into every information system that attempts to provide a complete and accurate model of the real world.

We use imperfection as the most general label. Information is perfect when it is precise and certain. Imperfection can be due to imprecision, inconsistency and uncertainty, the major aspects of imperfect data.

Imprecision and inconsistency are properties related to the content of the statement: either more than one world or no world is compatible with the available information, respectively. **Uncertainty** is a property that results from a lack of information about the world for deciding if the statement is true or false. **Imprecision** and **inconsistency** are essentially properties of the information itself whereas uncertainty is a property of the relation between the information and our knowledge about the world. Imprecision can be characterized by the presence of absence of an error component.

When several statements are combined, new aspects of imperfection can appear, in which cases some kind of error is always involved. An information can be **conflicting**: 'marital status = bachelor', 'spouse name = Joan'. The conflict in the data leads to an incoherence in the conclusions. Indeed the conclusion drawn from the data is that John is a 'married bachelor' as he has a spouse.

Logicians used **inconsistency** to define the **incoherence** that results from a conflicting information, like when you learn that at 3 p.m. the eggs were boiled and at 3.15 p.m. the same eggs were fresh.

The third aspect of informational imperfection, uncertainty, concerns the state of knowledge of an agent (denoted You, but the agent could even be a computer) about the relation between the world and the statement about the world. The statement is either true or false, but Your knowledge about the world does not allow You to decide if the statement is true or false. Certainty is full knowledge of the true value of the data. Uncertainty is partial knowledge of the true value of the data. Uncertainty results in **ignorance** (etymologically not knowing). It is essentially, if not always, an epistemic property induced by a lack of information. A major cause of uncertainty is imprecision in the data. Whether uncertainty is an objective or a subjective property is a still debated philosophical question left aside here.

Imperfect: Something is imperfect if it is incomplete, faulty.

Negligent: Someone who is negligent fails to deal with something or someone with the right amount of care or concern, or fails to do something which they ought to do. A lack of proper care or attention.

Imprecise: Something that is imprecise is not clear, accurate, or precise, not accurately expressed, not scrupulous in being inexact.

Vague: Vague is used to describe things that people say or write that are not clearly explained or expressed, so that they can be understood in different ways. It results in uncertain or ill-defined meaning.

Ambiguous: Something that is ambiguous is unclear or confusing because it can have more than one possible meaning. It can be due to vagueness.

Amphibologic: Synonymous to ambiguous.

Approximate: An approximate number, amount, time, position, etc. is close correct number, amount, etc., but is probably slightly different from it because it has been calculated quickly rather than exactly. An idea or description of something that is approximate provides some indication of what it is like but is not intended to be absolutely precise or accurate.

Fuzzy: If your thoughts are fuzzy or what you are thinking about is fuzzy, you are confused and cannot see an idea clearly or make a decision. You also describe something as fuzzy when it is not clearly defined and is indistinct or vague .

Missing: If something is missing, it is not in its place, it is lost, not present. You say that something is missing from a statement, report, etc. when it has not been included in it and you think that it should have been.

Incomplete: Something that is incomplete does not have all the parts that it should have, Not entered, not filled in.

Deficient: If someone or something is deficient in a particular thing, they do not have the full amount of it that they need in order to function normally or work properly. Someone or something that is deficient is not good enough for a particular purpose or standard.

Incomplete or insufficient in some essential respect.

Erroneous: Beliefs, opinions, methods etc. that are erroneous are incorrect or only partly correct.

Incorrect: Something that is incorrect is wrong, untrue , inaccurate .

Inaccurate: Something that is inaccurate is not correct, not precise and not conforming exactly to a standard or to truth.

Invalid: If an argument, conclusion, result, is invalid, it is not acceptable, because it is based on a mistake. Not sound logically.

Distorted: If an argument or a statement is distorted, its meaning becomes different and misrepresenting of what it should be.

Biased: Subject to a constant error.

Nonsensical: That do not make sense, absurd, foolish, stupid, ridiculous, untrue.

Meaningless: Without any meaning, but also: without importance or relevance.

Conflicting: If two or more things are in conflict, they are very different and not compatible. It seems impossible for each of them to be true, impossible for them to exist together, or for each of them to be believed by the same person.

Incoherent: If something is incoherent, it is unclear and difficult to understand, rambling in speech or reasoning.

Inconsistent: Someone who is inconsistent is unpredictable and behaves differently is a particular situation each time it happens, rather than doing or saying the same thing each time. Not compatible or not in harmony. Not constant to the same principles of thought or action.

Confused: Something is confused if it does not have any order or pattern and is difficult to understand because of this.

Random: Something that is random happens or is chosen without a definite plan, pattern, or purpose. Made or done without method or conscious choice.

Likely: Indicates that something is probably the case or will probably happen in a particular situation.

Believable: Something you think is likely.

Doubtful: That seems unlikely or uncertain.

Unreliable: If people, machines, or methods are unreliable, you cannot trust them or rely on them. That may be not relied on.

Irrelevant: An irrelevant fact, remark, is not connected with what you are focusing or dealing with, and is therefore not important. Not related to the matter in hand.

Ignorance: Lack of knowledge.

Undecidable: Which validity or truth cannot be decided, is questionable, or on which you cannot make your mind.

Gershon (1996) ●

Sources of **imperfection**:

- Corrupt data and information: analogous to errors in physics and engineering. Examples include errors in the location of targets reported by sensors.
- **Incomplete** data and information: quite frequent (most of the time, actually) in the real world.
- **Inconsistency**: pieces of data and information not consistent with each other or with what we already know.

- **Difficulty** in **understanding**: information itself is too complicated to understand.
- **Uncertainty**: data and information known, but the user is not sure about their existence or accuracy. The data and information could be exact, though. For example, "the information about the target flying around at 1,000 feet" is old and thus uncertain.
- **Imperfect presentation**: data and information could be exact, but a suboptimal presentation means the user cannot get the information in the allocated time or perceive the information wrongly. Examples include the poor choice of colors creating visual artifacts, or too fast a presentation creating information overload.

Strothotte et al. (1998) ●

Uncertainty describes the absence of information due to some reason. One simply does not know what something was like in the past or (for that matter) what it will be like in the future. In our context, uncertainty can arise for two reasons as defined – in general – by Kruse et al.:

Imprecision: this describes the fact that "one cannot measure or observe with an arbitrary degree of accuracy", this means that the existence of a certain feature can be safely assumed, but not its dimensions.

Incompleteness: this refers to the fact that certain information is unavailable, for example the answer to the question, "Did a given tower have windows, or not"?

Barceló (1999) ●

A **model** is a representation of some (not necessarily all) features of a concrete or abstract entity. It is a representation of a system showing not only the system components, but also the relationships between those components. Better than a mere analogy with the real world, we should imagine a model as a projection from a theory, that means one of the possible valid results from this theory.

Visual models are those that use graphical means for creating and editing the model, to obtain values for its parameters, and to understand its behaviour and structure.

Consequently, "**visualization**" can be defined as the process of creating a geometric representation of the regularity present in a data set:

joining points with lines, fitting surfaces to lines, or "solidifying" connected surfaces[3].

Unesco operational guidelines for the implementation of the world heritage convention - 2005 version[4]

Authenticity: the ability to understand the value attributed to the heritage depends on the degree to which information sources about this value may be understood as credible or truthful. Knowledge and understanding of these sources of information, in relation to original and subsequent characteristics of the cultural heritage, and their meaning as accumulated over time, are the requisite bases for assessing all aspects of authenticity.

Integrity is a measure of the wholeness and intactness of the natural and/or cultural heritage and its attributes.

Examining the conditions of integrity, therefore requires assessing the extent to which the property:

a) Includes all elements necessary to express its Outstanding Universal Value;

b) Is of adequate size to ensure the complete representation of the features and processes which convey the property's significance;

c) Suffers from adverse effects of development and/or neglect.

Hermon et al. (2001)

Incompleteness is a concept implicit in archaeological studies. Archaeology, and any other discipline that integrates archaeological data aiming at creating a virtual model, de facto do not provide enough data to establish a scientifically unquestionable model.To a certain point, all reconstructions remain "speculative".

We should therefore consider as **scientifically valid** a model that al-

3 The author quotes Gershon (López-Menchero Bendicho and Grande 2011).

4 The World Heritage Convention dates back to 1972; the first version of the operational guidelines was adopted by the Unesco World Heritage Committee in 1978. Authenticity and integrity are clearly defined starting from the version published in February 2005. Before that date, conditions of authenticity and integrity were listed without giving a definition of the two terms. For a history of the document with all its versions, see: <https://whc.unesco.org/en/guidelines/> (accessed 04.11.2024) lows us to quantify the "degree of speculation" and express it through established rules.

London Charter (2006-2009)

English / *Italian* versions of the document

Computer-based visualisation: the process of representing information visually with the aid of computer technologies / ***Visualizzazione/ rappresentazione digitale****: il processo di rappresentazione grafica digitale dell'informazione elaborata o creata con l'aiuto di tecnologie informatiche.*

Computer-based visualisation method: the systematic application, usually in a research context, of computer-based visualisation in order to address identified aim / ***Metodo di visualizzazione/ rappresentazione digitale****: l'applicazione sistematica, solitamente in un contesto di ricerca, della rappresentazione digitale per affrontare scopi identificati.*

Computer-based visualisation outcome: an outcome of computer-based visualisation, including but not limited to digital models, still images, animations and physical models / ***Prodotto della visualizzazione / rappresentazione digitale****: il prodotto della visualizzazione digitale, che include (ma non si limita a) modelli, immagini ferme e animazioni.*

Cultural heritage: the Charter adopts a wide definition of this term, encompassing all domains of human activity which are concerned with the understanding of communication of the material and intellectual culture. Such domains include, but are not limited to, museums, art galleries, heritage sites, interpretative centres, cultural heritage research institutes, arts and humanities subjects within higher education institutions, the broader educational sector, and tourism / ***Patrimonio culturale****: la Carta adotta una definizione ampia di questo termine, che racchiude tutti i settori dell'attività umana legati alla conoscenza della comunicazione della cultura materiale ed intellettuale. Tali settori comprendono (ma non si limitano a) musei, gallerie d'arte, siti culturali, centri interpretativi, istituti di ricerca sui beni culturali, materie artistiche e umanistiche all'interno degli istituti di educazione superiore, oltre al più ampio settore educativo ed al turismo.*

Dependency relationship: a dependent relationship between the properties of elements within digital models, such that a change in one property will necessitate change in the dependent properties. (For instance, a change in the height of a door will necessitate a corresponding change in the height of the doorframe.) / ***Relazione di dipendenza**: relazione fra le proprietà degli elementi all'interno dei modelli tridimensionali tale che il cambiamento di una proprietà implica il cambiamento di altre – dette dipendenti (ad esempio, la modifica dell'altezza di una porta determinerà necessariamente la modifica dell'altezza dell'intelaiatura).*

Intellectual transparency: the provision of information, presented in any medium or format, to allow users to understand the nature and scope of "knowledge claim" made by a computer-based visualisation outcome / ***Informazione sulla trasparenza**: l'informazione, attuata in qualsiasi mezzo o formato, che permette agli utenti di capire la natura e gli scopi del prodotto di una rappresentazione digitale e l'asserzione di conoscenza che porta.*

Paradata: information about human processes of understanding and interpretation of data objects. Examples of paradata include descriptions stored within a structured dataset of how evidence was used to interpret an artefact, or a comment on methodological premises within a research publication. It is closely related, but somewhat different in emphasis, to "contextual metadata", which tend to communicate interpretations of an artefact or collection, rather than the process through which one or more artefacts were processed or interpreted / ***Paradata**: la Carta definisce "paradata" come le informazioni riguardanti i procedimenti umani del capire ed interpretare i dati stessi (i paradata vengono in tal modo continuamente creati senza essere sistematicamente registrati o divulgati.) Esempi di paradata includono metodi di registrazione di note in un rapporto di laboratorio, descrizioni immagazzinate all'interno di un archivio strutturato che dimostra come l'evidenza sia stata usata per interpretare un manufatto, oppure un commento sulle premesse metodologiche all'interno di una ricerca pubblicata. È molto simile (ma in qualche modo diverso quanto all'enfasi) a "metadati contestuali", i quali tendono a comunicare interpretazione di un artefatto o di una collezione, piuttosto che il processo attraverso il quale uno o più artefatti sono processati o interpretati.*

Research sources: all information, digital and non-digital, considered during, or directly influencing, the creation of the computer-based visualisation outcomes / ***Fonti della ricerca****: tutte le informazioni, digitali e non, prese in considerazione durante la creazione di risultati per mezzo della visualizzazione digitale o che vi abbiano influito direttamente.*

Subject community: a group of researchers generally defined by a discipline (e.g. Archaeology, Classics, Sinology, Egyptology) and sharing a broadly- defined understanding of what constitute valid research questions, methods and outputs within their subject area / ***Comunità di soggetti****: un gruppo di ricercatori generalmente definiti da una disciplina (ad esempio, Archeologia, Egittologia) e che condividono un ampio e definito contesto nel quale vengono effettuate valide ricerche, poste domande, applicati metodi e divulgati risultati all'interno del campo di studi.*

Sustainability strategy: a strategy to ensure that some meaningful record of computer-based visualisation processes and outcomes is preserved for future generations / ***Strategia di sostenibilità****: una strategia per garantire che significative testimonianze della procedura di rappresentazione digitale e dei suoi risultati venga conservata per le generazioni future.*

Icomos Ename (2008) ●●

Cultural Heritage Site refers to a place, locality, natural landscape, settlement area, architectural complex, archaeological site, or standing structure that is recognized and often legally protected as a place of historical and cultural significance.

The two main concepts that emerge from this document are **interpretation** and **presentation**.

Interpretation refers to the full range of potential activities intended to heighten public awareness and enhance understanding of cultural heritage site. These can include print and electronic publications, public lectures, on-site and directly related off-site installations, educational programmes, community activities, and ongoing research, training, and evaluation of the interpretation process itself.

Presentation more specifically denotes the carefully planned communication of interpretive content through the arrangement of interpretive information, physical access, and interpretive infrastructure at a cultural heritage site. It can be conveyed through a variety of technical means, including, yet not requiring, such elements as informational panels, museum-type displays, formalized walking tours, lectures and guided tours, and multimedia applications and websites.

Interpretation is also related to:

Interpretive infrastructure refers to physical installations, facilities, and areas at, or connected with a cultural heritage site that may be specifically utilised for the purposes of interpretation and presentation including those supporting interpretation via new and existing technologies.

Site interpreters refers to staff or volunteers at a cultural heritage site who are permanently or temporarily engaged in the public communication of information relating to the values and significance of the site.

Adam (2006) ●

The term **authenticity** has different definitions depending on the context of its use. Duranti (1998) writes, "diplomatically authentic documents are those which were written according to the practice of the time and place indicated in the text, and signed with the name(s) of the person(s) competent to create them. Historically authentic documents are those, which attest to events that actually took place or to information that is true".

Clark (2010) ●

"It is the contention of this paper that the notion of "**reconstructing**" the past is not only a misnomer but one that has been detrimental to the discipline. This holds true for conventional archaeology as well as virtual. We should only be talking about "**constructions**" of the past and rarely, if ever, about reconstructions. We are always constructing models, whether visual, verbal, or some other type, which are tools for understanding, not statements of reality. The criticisms that have often been leveled against virtual visualizations have been largely due to calling, and thinking about, visualizations as reconstructions of some aspect of the past rather than regarding them for what they are—models. Calling these models reconstructions is not only fallacious but has hindered the acceptance and use of virtual archaeology by the larger professional community".

He discusses two apparently contrasting ideas: 1) no matter what name we give to something, it does not change the essential character of it; 2) terminology does matter: "There is indeed power in words. Words, including and perhaps especially names and terminology, reflect as well as shape what we think about things. Those terms convey meaning to others whose perceptions are then influenced, subtly or profoundly".

Thoomu (2010)

Uncertainties in the **input** due to:

- Missing components or errors in the data.
- Variability in the data because of imperfect observations.
- Random sampling errors.
- Inaccuracy in measurement.

Uncertainties in **models** due to:

- Unfamiliar functional relationship among the components even if the functions of individual components are known.
- Inherent performance of the system and effects of the surroundings.
- Ambiguity in predicting the final outcome. Qualms introduced by approximation techniques used to solve a set of equations that characterize some model.

Other sources of uncertainty:

- Vaguely defined concepts and terminology.
- Lack of communication.

Though there are many sources of uncertainty, as described by researchers from different fields, the main reasons behind it are:

• **Variability**

Variability is a characteristic of being subjected to changes. The variation could be in input, system, or performance of the system, etc.

• **Lack of knowledge**

Lack of knowledge about the system, inadequate awareness of component interactions in a system, insufficient and non reliable information, contribute for the occurrence of uncertainty.

Beacham (2010)

Realism:

1) Treatment of forms, colours, space, etc., in such a manner as to

emphasize their correspondence to actuality or to ordinary visual experience[5].

2) Fidelity to nature or to real life; representation without idealization, and making no appeal to the imagination; adherence to the actual fact[6].

Paradata according to the London Charter (employing the term coined by my CVL colleague, Drew Baker) is "Information about human processes of understanding and interpretation of data objects. Examples of paradata include descriptions stored within a structured dataset of how evidence was used to interpret an artefact, or a comment on methodological premises within a research publication. It is closely related, but somewhat different in emphasis, to 'contextual metadata', which tend to communicate interpretations of an artefact or collection, rather than the process through which one or more artefacts were processed or interpreted".

Beacham et al. (2011) ●

Archaeological reconstructions of ancient houses and villas: they typically limit themselves to the precise structural and decorative evidence available;

Social and art historians' point of view: the whole architectural and decorative ensemble is necessary for an understanding of the dynamic use of space in antiquity as a complex system of signification.

Rocheleau (2011) ●●

Original French version / *translation by Irene Cazzaro*

Il est donc peu étonnant de constater qu'une analyse des vingt dernières années au sujet de l'évolution de la 3D et de la réalité virtuelle en sciences historiques fasse ressortir des principes directeurs essentiellement liés aux deux mêmes domaines, l'archéologie et les études patrimoniales, au point où il est courant aujourd'hui de parler de virtual archaeology ou de virtual heritage. / *It is therefore hardly surprising to note that an analysis of the last twenty years on the subject of the evolution of 3D and virtual*

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5 See <http://dictionary.reference.com/browse/realism>.

6 See <https://www.webster-dictionary.org/definition/realism>.

reality in historical sciences reveals guiding principles essentially linked to the same two domains, archaeology and heritage studies, to the point that it is common today to speak of virtual archaeology or virtual heritage.

Par **scientifique**, nous entendons un modèle 3D qui résulte d'un programme de recherche conduit de manière traditionnelle: accessibilité aux sources employées, confrontation de ces dernières, explication des méthodes utilisées et du processus pour en arriver à la modélisation finale, etc. En clair, tout ce qui permet au chercheur de comprendre le raisonnement derrière la réalisation d'un modèle (et qui peut se comparer à l'appareillage critique d'un texte). Tout le contraire d'un modèle créé par un studio multimédia dont il serait impossible de valider l'authenticité historique parce que le processus décisionnel de restitution n'est pas documenté. / *By* ***scientific****, we mean a 3D model resulting from a research program carried out in a traditional way: accessibility to the sources used, comparison of the latter, explanation of the methods used and the process to arrive to the final modeling, etc. Clearly, anything that allows the researcher to understand the reasoning behind the realization of a model (and which can be compared to the critical apparatus of a text). Quite the opposite of a model created by a multimedia studio whose historical authenticity would be impossible to validate because the restitution decision-making process is not documented.*

5 points based on rules that have been laid down:

Le **réalisme** est le thème le plus ancien et, dans une certaine mesure, le plus évident. Cette course effrénée vers le réalisme visuel provient, en partie, de l'objectif initial des restitutions et des reconstitutions virtuelles, qui a été la diffusion de l'histoire pour le grand public et la volonté de faire voir le passé / ***Realism*** *is the most ancient theme and, to some extent, the most evident one. This frantic rush towards visual realism partly comes from the initial aim of virtual renditions and reconstructions, which was the dissemination of history for the general public and the desire of showing the past.*

Transparence: Vers la fin des années 1990, lorsque des chercheurs universitaires ont commencé à s'intéresser aux modélisations virtuelles en 3D pour leur travail, l'objectif principal est devenu, avec raison, la **crédibilité scientifique** du procédé de restitution virtuelle. Ce principe a rapidement rejoint une des considérations qui, depuis longtemps, anime une grande partie des chercheurs des sciences historiques: la capacité de pouvoir consulter les sources de tout type de travail pour mieux comprendre le raisonnement d'un auteur et attester de sa rigueur. Ce concept, transposé dans le monde des technologies, se nomme la transparence. Cela consiste à rendre les étapes du processus de création d'un modèle 3D accessibles par l'intermédiaire de ce que nous appelons des métadonnées et des paradonnées / ***Transparency****: Towards the end of the 1990s, once university researchers started focusing on 3D virtual reconstructions for their work, the main purpose became, with good reason, the* ***scientific credibility*** *of the virtual reconstruction process. This principle has rapidly reached one of the considerations that, for a long time, has guided a large part of researchers in historical sciences: the capability to consult the sources of every type of work in order to better understand the reasoning of an author and assess its rigour. This concept, transposed in the world of technologies, is called transparency. It consists in making the steps of the creation process of a 3D model accessible by means of what we call metadata and paradata.*

Le problème de l'**incertitude**, dans son acception la plus large, concerne l'ensemble des modèles 3D virtuels, car même le scientifique le plus aguerri ne peut être absolument certain que ce qu'il réalise ou construit reproduit parfaitement l'ancienne réalité. Faire état des incertitudes entourant la restitution renforce ainsi la transparence et exprime une forme d'honnêteté intellectuelle / *The problem of* ***uncertainty****, it its widest meaning, involves all 3D virtual models, because even the most seasoned scientist cannot be absolutely sure that what he creates or constructs perfectly reproduces ancient reality. Reporting the uncertainties surrounding the rendition thus reinforces transparency and expresses a form of intellectual honesty.*

Toutefois, pour qu'ils aient un réel impact, les modèles 3D doivent également être **pérennes**, comme les articles scientifiques d'aujourd'hui ou les maquettes **de** l'époque. Il est en effet primordial de prévoir la sauvegarde à long terme de ces réalisations virtuelles, au même titre que n'importe quel autre patrimoine historique, comme le demande notamment la Charte de l'UNESCO sur la conservation du patrimoine numérique[7] / *However, in order to ensure they have a significant impact, 3D models should also be **sustainable**, such as the modern scientific articles or the ancient models. It is indeed essential to foresee the long-term preservation of these virtual realisations, as well as any other example of historical heritage, as called in the UNESCO Charter on the preservation of digital heritage.*

Enfin, il devient de plus en plus courant de suivre des **standards internationaux** et d'utiliser une **méthode** dite **scientifique** pour la création d'un modèle 3D. Il s'agit simplement de mettre en pratique les principes que nous venons d'évoquer. Quelques initiatives internationales proposent leurs standards et leur méthode de travail qui permettent d'encadrer la création de modèles 3D numériques à caractère historique et patrimonial / *Finally, it becomes increasingly common to follow **international standards** and to use a so-called **scientific method** for the creation of a 3D model. It is simply a question of putting the principles that we just mentioned into practice. Some international initiatives propose their standards and their working method that provide a framework for the creation of 3D digital models for history and cultural heritage.*

Seville Principles (2011)[8] ●●

English / *Spanish* versions of the document

Virtual archaeology: the scientific discipline that seeks to research and develop ways of using computer-based visualisation for the comprehensive management of archaeological heritage / ***Arqueología Virtual**: es la disciplina científica que tiene por objeto la investigación y el desarrollo de formas de aplicación de la visualización asistida por ordenador a la gestión integral del patrimonio arqueológico.*

Archaeological heritage: the set of tangible assets, both movable and immovable, irrespective of whether they have been extracted or not and

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7 Unesco Charter on the Preservation of Digital Heritage, Paris, 29 September to 17 October 2003.
<http://portal.unesco.org/en/ev.php-URL_ID=17721&URL_DO=DO_TOPIC&URL_SECTION=201.html> (accessed 23/09/2020)

8 See also: Hacia una Carta Internacional de Arqueología Virtual. El Borrador SEAV by Víctor Manuel López-Menchero Bendicho and Alfredo Grande.

whether they are on the surface or underground, on land or in water, which together with their context, which will also be considered a part of archaeological heritage, serve as a historical source of knowledge on the history of humankind. The distinguishing feature of these elements, which were or have been abandoned by the cultures that produced them, is that they may be studied, recovered or located using archaeological methodology as the primary method of research, using mainly excavation and surveying or prospection techniques, without compromising the possibility of using other complementary methods for knowledge / ***Patrimonio arqueológico**: es el conjunto de elementos materiales, tanto muebles como inmuebles, hayan sido o no extraídos y tanto si se encuentran en la superficie o en el subsuelo, en la tierra o en el agua, que junto con su contexto, que será considerado también como formante del patrimonio arqueológico, sirven como fuente histórica para el conocimiento del pasado de la humanidad. Estos elementos, que fueron o han sido abandonados por las culturas que los fabricaron, tienen como sello distintivo el poder ser estudiados, recuperados o localizados usando la metodología arqueológica como método principal de investigación, cuyas técnicas principales son la excavación y la prospección, sin menoscabo de la posibilidad de usar otros métodos complementarios para su conocimiento.*

Comprehensive management: this includes inventories, surveys, excavation work, documentation, research, maintenance, conservation, preservation, restoration, interpretation, presentation, access and public use of the material remains of the past / ***Gestión integral**: comprende las labores de inventario, prospección, excavación, documentación, investigación, mantenimiento, conservación, preservación, restitución, interpretación, presentación, acceso y uso público de los restos materiales del pasado.*

Virtual restoration: this involves using a virtual model to reorder available material remains in order to visually recreate something that existed in the past. Thus, virtual restoration includes virtual anastylosis / ***Restauración virtual**: comprende la reordenación, a partir de un modelo virtual, de los restos materiales existentes con objeto de recuperar visualmente lo que existió en algún momento anterior al presente. La restauración virtual comprende por tanto la anastilosis virtual.*

Virtual anastylosis: this involves restructuring existing but dismembered parts in a virtual model / ***Anastilosis virtual:*** *recomposición de las partes existentes pero desmembradas en un modelo virtual.*

Virtual reconstruction: this involves using a virtual model to visually recover a building or object made by humans at a given moment in the past from available physical evidence of these buildings or objects, scientifically-reasonable comparative inferences and in general all studies carried out by archaeologists and other experts in relation to archaeological and historical science / ***Reconstrucción virtual:*** *comprende el intento de recuperación visual, a partir de un modelo virtual, en un momento determinado de una construcción u objeto fabricado por el ser humano en el pasado a partir de las evidencias físicas existentes sobre dicha construcción u objeto, las inferencias comparativas científicamente razonables y en general todos los estudios llevados a cabo por los arqueólogos y demás expertos vinculados con el patrimonio arqueológico y la ciencia histórica.*

Virtual recreation: this involves using a virtual model to visually recover an archaeological site at a given moment in the past, including material culture (movable and immovable heritage), environment, landscape, customs, and general cultural significance / ***Recreación virtual:*** *comprende el intento de recuperación visual, a partir de un modelo virtual, del pasado en un momento determinado de un sitio arqueológico, incluyendo cultura material (patrimonio mueble e inmueble), entorno, paisaje, usos, y en general significación cultural.*

Favre-Brun (2011) ●

Original French version / *translation by Irene Cazzaro*

Le concept d'incertitude possède un champ sémantique très large pour lequel aucun consensus sur ses multiples significations n'a pu être trouvé. Les terminologies utilisées pour exprimer l'**incertitude** sont vagues et aussi nombreuses que le disciplines qui l'étudient ou les modes de perception. […] En archéologie, l'interprétation des données, fondée sur des données lacunaires, ambigües, imprécises, hétérogènes et issues de séries discontinues, appartient au domaine du plausible / *The concept of* ***uncertainty*** *has a huge semantic field for which no consensus on its various meanings has been found. The terminologies used to express uncertainty are vague and as numerous as the disciplines that study it or the perception modes. […] In archaeology, the interpretation of data, based* *on data that are incomplete, ambiguous, imprecise, heterogeneous and originated from discontinuous series, belongs to the domain of plausible*[9].

L'usage de nombreux synonymes révèle le «caractère multi-facettes» de l'incertitude et souligne sa nature objective ou subjective, quantifiable ou non, et réductible ou irréductible / *The use of several synonyms reveals the «multi-faceted character» of uncertainty and underlines its objective or subjective nature, quantifiable or not, and reducible or irreducible10.*

Les **nuances** recensées à travers la littérature expriment la confusion générale lorsqu'il s'agit de qualifier l'incertitude, souvent confondues avec les sources et les types d'incertitude / *The* ***nuances*** *examined through literature express the general confusion when it comes to qualifying uncertainty, often confused with the sources and types of uncertainty.*

Classifications de l'incertitude: il existe plusieurs classifications de l'incertitude. La première répartit neuf types d'incertitude en trois catégories relatives à la qualité de l'information, à sa cohérence et à son objectivité / ***Classifications of uncertainty****: there are many classifications of uncertainty. The first one assigns nine types of uncertainty to three categories related to the quality of information its coherence and its objectivity.*

9 Bertoncello 2013
10 Dungan, Gao, Pang 2002; Thoomu 2010

Qualité / *Quality*	Cohérence / *Coherence*	Objectivité / *Objectivity*
Exactitude/erreur: difference entre l'observation et la réalité Exactitude de la collecte Erreurs de traitement Tromperie ***Exactness/error:*** *difference between observation and reality* - *Exactness of the collection* - *Treatment errors* - *Deception*	**Cohérence:** Concordance entre les composants de l'information - Conflits - Modèle/observation - Cohérence ***Coherence:*** *harmony between the components of information* - *Conflicts* - *Model/observation* - *Coherence*	**Crédibilité:** Fiabilité des sources - Fiabilité - Proximité - Justesse - Motivation de la source ***Credibility:*** *reliability of sources* - *Reliability* - *Proximity* - *Accuracy* - *Motivation of the source*
Précision: exactitude de la mesure - Précision de la collecte ***Precision:*** *exactness of the measure* - *- Precision of the collection*	**Lignage:** Conduit à travers lequel est passée l'information - Traduction - Transformation - Interprétation ***Lineage:*** *channel through which information passes* - *Translation* - *Transformation* - *Interpretation*	**Subjectivité:** Niveau d'interprétation ou de jugement - Jugement analytique ***Subjectivity:*** *level of interpretation or judgement* *- Analytical judgement*
Exhaustivité: Niveau de complétude de l'information - Exhaustivité composite - Exhaustivité des informations - Séquence incomplete ***Exhaustiveness:*** *Level of completeness of information* - *Composite exhaustiveness* - *Exhaustiveness of information* - *Incomplete sequence*	**Actualité:** Lacunes temporelles entre l'apparition de l'information, sa collecte et son utilisation - Lacunes temporelles - Versions ***Topicality:*** *temporal gaps between the appearance of information, its collection and its use* - *Temporal gaps* - *Versions*	**Corrélation/dépendance:** Indépendance de la source par rapport à d'autres informations - Indépendance de la source ***Correlation/dependence:*** *Independence of the source in relation to other information* - *- Independence of the source*

Perlinska (2013)

There has been many articles written concerned with the issue of the adequacy of the word "**reconstruction**" in archaeology. I will use the words ***model*** or ***virtual simulation*** instead, as proposed by Jeffrey Clark. "Reconstruction", as pointed out by many authors, assumes that we know precisely how the things were in the past and that we are reproducing an exact image of the past. It is hard to uproot this concept, as there has not been any convincing replacements proposed. Model and virtual simulation might still be too ambiguous, but it is not in the scope of this thesis to define a new technical terminology. In this work, model or virtual simulation will be used alternatively to denominate a 3D virtual construct done on the basis of the remains of the ancient Pompeian house V 1,7. In some instances, where those words can cause the confusion or may seem unclear, I will continue to use the word "reconstruction".

Virtual Reality (in short VR) can be defined as a cyber space environment (sometimes called a computer simulation), resembling the real world or not, that can be explored by people, and, in some cases, interacted with. It should give the viewer a sense of telepresence, which is a feeling of being physically present in this environment through a medium (like 3D glasses). For each visitor, the sensual perception (sometimes also other senses than vision are stimulated) will be slightly different, depending on each individuals physical and mental condition.

The VR environment enables its users (depending on the level of accessibility) to perceive the model and to freely move around in it, but also to interact with it in a variety of ways. This creates interesting possibilities for archaeological research which have not been completely explored yet and – looking at the intense pace at which technology develops today – might never be fully researched.

The definition of **probability** assumes that the number of all possible cases is known. Unfortunately, we cannot hope for that in our discipline. Thus, probability is not a word we should use. In some cases, words such as uncertainty and confidence were used instead. ***Uncertainty*** is a misleading word: an uncertainty map shows the level of our certitude, or incertitude. This is very confusing, whereas ***confidence***, in my opinion, is too close to actually believe and have faith in something (probably in the archaeological knowledge of the archaeologist).

The most suitable word could be plausibility. It is a more "humanistic" equivalent of the word probability. It states the possibility of an event to occur, but the chance for it is not calculated by any mathematical formula. I think that in future implementation plausibility map should be forced as a standard nomenclature.

However, as I stated before, the introduction of a new terminology is not within the scope of this thesis. Under those circumstances, I would like to use this unfortunate probability map, but to do so, the term requires proper definition.

Thus, a **probability map** should be understood as additional information to the virtual visualization, one that indicates the level of the researchers certitude in his knowledge about how each of the individual features looked like. It has not much to do with the "objective" past Roman world, but rather with our ideal imaginations that we have about it. The goal is not only to provide a "pretty picture" (this is something that everybody seeks, regardless of what they claim), but also to collect information about all the features and visualize it in as high a quality as technology allows us to.

Lengyel and Toulouse (2014) ●

The expression **uncertain knowledge** underlines the large and productive field between knowledge on one hand and the lack of knowledge on the other hand pointing out the other states of knowledge in between. Uncertain knowledge takes into account **incomplete knowledge**, e. g. if some parts of a structure are known while other parts are unknown, but also **contradictory knowledge**, that is if the stringent deduction of prerequisites allow contradictory yet equivalent conclusions. Incomplete and contradictory knowledge is then summarized as uncertain knowledge.

Demetrescu and Fanini (2015) ●●

Scientific process behind an archaeological reconstruction: it includes not only the specialists' hypotheses regarding a specific context in order to reconstruct its "original aspect" in a given historical time period, but also the collection and the use of the "sources".

Sources: they comprise all the physical evidence (such as discoveries made during excavation or pieces from a museum's collection), historical assumptions (i.e. in Roman times outside the city wall and along the main road there was a necropolis), and documents (drawings or writings) from the past that testify to the lost aspects of the archaeological site as well as its 3D survey and stratigraphic reading.

Lost context: a context that is no longer existent and/or has been completely or partially "lost" over time due to various causes (war, neglect, environmental factors etc…).

Extended matrix (EM): as defined in its 1.0 version (Demetrescu 2015), it is a formal language specifically designed for the reconstruction of lost contexts and operates with the same tools already in use in the archaeological domain in order to manage time sequences (matrix of Harris) and data granularity (stratigraphy). The version 1.1 of the Extended Matrix adds a complete support for 3D representation of extended matrices and scientific publication of the whole dataset behind a virtual reconstruction hypothesis. The EM is the theoretical and methodological background, usable even outside a digital environment. It is about scientific-driven content creation.

Extended matrix framework (EMF): the integration of the EM with digital tools for 3D representation of virtual reconstructions and visual inspection of extended matrices is identified with the expression Extended Matrix Framework (EMF). It is about technological-driven solutions.

Amico et al. (2017) ●

If the term '**authentic**' is used to define something original and unique, the authenticity of digital objects or their physical replicas, generated from a real object, cannot be applied because 'all digital object are copies' (Lynch 2000) and infinitely replicable and modifiable. In this case, the term 'faithful' seems to fit better.

B.
APPENDIX 2. SOME DOCUMENTATION SCHEMES

Grellert and Pfarr-Harfst (2019) “Die Rekonstruktion-Argument-Methode: minimaler Dokumentationsstandard im Kontext digitaler Rekonstruktionen”: German original version and English translation.

Projekt → Projektname → Zusatzinformation für die Projektbezeichnung → Kurzbeschreibung des Projektes → Ausführliche Beschreibung des Projektes → Repräsentatives Bild der Rekonstruktion → Entstehungszeit des Bauwerks/Stadtanlage → Laufzeit des Projektes → Institution, die die Rekonstruktion durchgeführt hat → Bearbeiterinnen / Bearbeiter → Wissenschaftliche Beratung → Auftraggeber/Kooperationspartner → Sponsoren → Eingesetzte Hard-/Software → Geokoordinaten des rekonstruierten Bauwerks / Stadtanlage → Website des Projektes → Name des Ansprechpartners mit E-Mail-Adresse/Telefonnummer → Weitere Angabe zur Institution: Allgemeine E-Mail-Adresse und Telefonnummer, Website, Anschrift, Kurzname der Institution → Renderings bzw. Filme des fertiggestellten Projektes **Bereiche** → Anzahl der Bereiche (1: n) → Bezeichnung	**Project** → project name → Additional information for the project designation → Brief description of the project → Detailed description of the project → Representative image of the reconstruction → Time of construction of the building/city facility → Duration of the project → Institution that carried out the reconstruction → Editors → Scientific advice → Client/cooperation partner → sponsors → Hardware/software used → Geo-coordinates of the reconstructed building / city complex → Website of the project → Name of contact person with e-mail address/telephone number → Additional information about the institution: general e-mail address and telephone number, website, address, short name of the institution → Renderings or films of the completed project **Areas** → number of areas (1: n) → designation

→ Übersichtsbild, das den Bereich verortet, und Bildunterschrift → Anzahl der Varianten für einen einzelnen Bereich (1: n) → Wenn gewünscht, ausführlichere Beschreibung des Bereichs	→ Overview image that locates the area, and caption → Number of variants for a single area (1:n) → If desired, more detailed description of the area
Varianten → Bezeichnung der Variante (Standardbezeichnung 1) →Bewertung der Varianten in gesichert, wahrscheinlich, möglich und hypothetisch → Angabe, ob die Variante Bestandteil der Endpräsentation des Projektes ist → Rekonstruktion–Argument–Quelle	**Variants** → Designation of the variant (standard designation 1) →Evaluation of variants in saved, probable, possible and hypothetical → Specification whether the variant is part of the final presentation of the project → Reconstruction-argument-source reconstruction
Rekonstruktion → Screenshot/Rendering (1: n) → Bildunterschrift	**Reconstruction** → Screenshot/Rendering (1:n) → Caption
Argument → Freie Texteingabe	**Argument** → Free text entry
Quelle → Abbildung (1: n) → Bildunterschrift → Autorin/Autor → Entstehungszeit → Archiv → Signatur → Copyright → Direkt-URL, wenn vorhanden → Veröffentlicht von → Titel der Veröffentlichung → Herausgeber der Veröffentlichung → Titel des Sammelbands → Ort der Veröffentlichung → Jahr der Veröffentlichung → Seite → Eigener Kommentar für weitere Informationen	**Source** → Figure(1:n) → Caption → Author → Time of origin → Archive → Signature → Copyright → Direct URL, if available → Published by → Title of publication → Publisher of the publication → Title of the anthology → Place of publication → Year of publication → Page → Own comment for further information

→ Art (3D-Laser-Scan, SFM-Bauaufnahme, Befundzeichnung, Befund- skizze, Foto der archäologischen / architektonischen Reste, Fotos des bestehenden Bauwerks, Bauplan, Entwurfsplan, zeichnerische Bauaufnahme, haptisches Rekonstruktionsmodell, Rekonstruktionszeichnung, Textquelle, historische Zeichnung, historisches Gemälde, historische Filmaufnahme).	→ Type (3D laser scan, SFM building survey, finding drawing, finding sketch, photo of the archaeological/architectural remains, photos of the existing structure, building plan, draft plan, drawing of the building survey, haptic reconstruction model, reconstruction drawing, text source, historical drawing, historical painting , historical film recording).

Statham (2019) "Scientific rigour of online platforms for 3D visualisation of heritage"

The proposed information package should include:
» Descriptive name
» Type of 3D visualisation
» Level of certainty of the reconstruction
» Description
» Original location
» Current location
» Date
» Author
» Team responsible for the visualisation
» Team supervisor
» Funding
» Part of project(s)
» Project description
» Related publications
» Related visualisations
» Sources
» Visualisation methodology and tools

Wacker and Bruschke (2019) "Dokumentation von Digitalen Rekonstruktionsprojekten": German original version and English translation.

[…] Dazu empfiehlt es sich, Dokumentationsstrategien zu entwickeln, die diese Aktivitäten tatkräftig verbessern und strukturieren. Im Konkreten bedeutet das die Dokumentation der	[…] It is advisable to develop documentation strategies that actively improve and structure these activities. In concrete terms, this means the documentation of the
→ Kenntnislage: Es ist darzustellen, was die Visualisierung anstrebt, und von welcher Art und welchem Ausmaß die faktischen Unsicher- heiten sind.	→ Knowledge: It must be shown what the visualization is aiming for and what the type and extent of the factual uncertainties are.
→ Forschungsquellen: Die genutzten Quellen einschließlich ihrer Herkunft sollen aufgelistet werden.	→ Research sources: The sources used, including their origin, should be listed.
→ Prozesse: Alle auswertenden, analytischen, deduktiven, interpretativen und kreativen Entscheidungen sollen so zur Verfügung stehen, dass die Beziehung zwischen Quelle, implizitem Wissen, expliziten Schlussfolgerungen und den Visualisierungsergebnissen verstanden werden kann.	→ Processes: All evaluating, analytical, deductive, interpretative and creative decisions should be available in such a way that the relationship between the source, implicit knowledge, explicit conclusions and the visualization results can be understood.
→ Methoden: Anwendern, die mit den gewählten Visualisierungsmethoden nicht vertraut sind, sollte eine Beschreibung der Methoden zur Verfügung gestellt werden. Außerdem sollte erklärt werden, warum die gewählte Methode die geeignetste ist (in Bezug auf Leitsatz 2 der Londoner Charta Ziele und Methoden). Die Dokumentation sollte darüber hinaus bei der »Artikulation impliziten Wissens« und der »Identifizierung der verschiedenen Terminologien« (mit Blick auf interdisziplinäre Projekte) helfen.	→ Methods: Users who are not familiar with the selected visualization methods should be provided with a description of the methods. It should also explain why the method chosen is the most appropriate (in relation to Principle 2 of the London Charter Objectives and Methods). The documentation should also help with the "articulation of implicit knowledge" and the "identification of the various terminologies" (with a view to interdisciplinary projects).
→ Verknüpfung von Abhängigkeiten: »Die Art und Wichtigkeit der wesentlichen, hypothetischen Abhängigkeitsverhältnisse zwischen den Elementen [sollen] identifiziert und die zugrunde liegenden Folgerungen verstanden werden können.«	→ Linking of dependencies: "The type and importance of the essential, hypothetical dependencies between the elements [should] be identified and the underlying conclusions understood."
→ Formate und Standards: Die Dokumentation soll durch die »Nutzung der effektivsten verfügbaren Medien« und Standards in einer Form verbreitet werden, dass deren Benutzung sowie die Aufnahme in Zitationsdatenbanken vereinfacht werden.	→ Formats and standards: The documentation should be disseminated through the "use of the most effective available media" and standards in a form that simplifies its use and inclusion in citation databases.

Scheme used in DFG repository

It is mainly based on the following points:

» Model representation
» Model description
» Reconstructed period (WissKi entity)
» Model copyright (WissKi entity)
» Model creation
» Object
» Project
» Native file
» Documentation
» Viewer file upload

Example of metadata related to the Speyer synagogue (1250) entry in the DFG Viewer:

Model Representation
Polygonal
Model Description
The model depicts the Speyer synagogue at around 1250 AD.
Reconstructed period
1250
Model Copyright
License
CC-BY-NC Attribution-NonCommercial
Author(s)
Name
Irene Cazzaro
Affiliation
University of Bologna
ORCID ID
https://orcid.org/0000-0002-9484-1980
Holder (Organization)
Name
Institute of Architecture, Univeristy of Applied Scinces Mainz

VIAF ID
https://viaf.org/viaf/170713989/
Website
https://architekturinstitut.hs-mainz.de/
Model Creation
Used Software
Rhino 5
SketchUp 2017
Modeling Techinque
Polygonal modeling
NURBS and curve modeling
Boolean modeling
Creation Time Span
2022-03-08 — 2022-04-11
Participant(s)
Object
Name
Synagogue in Speyer
Synagogue Speyer
Alternative Name(s)
Former Synagogue in Speyer [en]
Synagoge Speyer
Type
Synagogue
Location
City
Speyer
Geonames ID
http://www.geonames.org/2830582/speyer.html
City
Speyer
Historical Relations
City
Speyer
Wikidata
https://www.wikidata.org/wiki/Q64825449

Wikipedia
https://en.wikipedia.org/wiki/Jewish_courtyard,_Speyer
Project
Title
Case Study of the reconstruction of the Synagogue in Speyer in 800
Acronym
CaSt: SpSya1250
Outcome(s)
3d representation
3d information model
Project Time Span
2022-02 — 2022-06
Description
A case study of the reconstruction of the synagogue in Speyer to test the possibility of saturating the 3D model with scientific information in modeling programs and the preservation of this information during export to various file formats. The most popular 3D modeling software in the field of digital heritage (Blender, Maya, 3DS Max, Sketchup, Archicad, Rhino, Cinema4D, LightWave 3D, Revit, Allplan) listed in the following publications / research were selected for testing: “3D content in Europeana task force” , “Sketchfab Cultural Heritage User Survey 2019 Results”, “3D Digitization in Cultural Heritage“ by Emma Cieslik and “First Results of Community Survey” made as a part of 3D-DFG Viewer project.
Participant(s) (Organizations)
Name
Department of Architecture of the University of Bologna
VIAF ID
https://viaf.org/viaf/304306047
Website
https://phd.unibo.it/architettura/en
Role
Conceptor
Native File
20220526_speyer synagogue.skp

Documentation
documentation_template_01_modifiche_3.docx
documentation_template_02_1.docx
Viewer File Name
https://3d-repository.hs-mainz.de/sites/default/files/2022-05/20220526_speyer_synagogue_ZIP/gltf/20220526_speyer_synagogue.glb

Linked data technologies: URI, RDF, RDFS, OWL, ontologies, SPARQL

Four rules (or good practices) to follow in order to arrive to linked data have been identified (Chandler and Polkinghorne 2016):

(1) Use URI to identify objects;
(2) Use http URI so that the objects can be identified by humans and machines;
(3) Provide useful information about the object by using standards such as RDF (Resource Description Framework, it gives semantic structure);
(4) Include links to other URIs.

The URI identifies univocally a source, for example a name, expressed in a recognisable way.

At the following level we find XML to give structure to data and RDF to define the syntax.

These file formats support the higher level of the language to establish a non-arbitrary meaning (RDFS and OWL), the language to query data (SPARQL) and the exchange rules on the web (RIF).

This leads to a unifying logic, where new knowledge can derive from information. It can be used as a proof, being it a standard to represent evidence, based on concepts such as credibility and reliability.

1. some acronyms explained:

URI: Uniform Resource Identifier

URN: Uniform Resource Name, it can be used to create URIs.

URL: Uniform Resource Locator, it can be used to create URIs.

IRI: Internationalised Resource Identifier, it also used non-ASCII characters.

OWL: Ontology Web Language, recommended by W3C.

2.

To add syntax and semantics, we use RDF and XML.

XML format gives the structure, whereas RDF is a syntax based on triples. A triple is an oriented graph with subject, predicate, object.

A source is everything that can be described with RDF: a web page, a person, a work, a city, an animal, an event... It can be described by attributing it an URI.

In order to translate a database into graph of this kind, we need serialisation, that is the use of specific computer languages such as RDF/XML, TURTLE, N-TRIPLES, JSON_LD. The last one is the most popular, but none of these is the "best" language: it depends on what we need.

RDFS (where "s" stands for "schema") is necessary to give a meaning to the triple: it is a way to restrict the domain and range of a relation (for example, only a field "author" can be associated to a field "work of art" through a relation "is the author of").

Thus, it is a group of classes and properties to express restrictions on associations of terms and avoid statements that could be syntactically correct, but meaningless.

A *domain* limits the application of properties to individuals of one or more classes.

A *range* limits the application on the basis of what is allowed by the domain.

RDF and RDFS still have expressiveness limits: for the principles of the semantic web, sophisticated programs should reason on data, thus we need a technological infrastructure.

OWL and the ontologies are tools of semantic disambiguation: that means that objects should be univocally identifiable and software agents should recognize and associate them. The ontologies should be public and shared between users.

Ontologies are controlled vocabularies that describe in shared, formal, explicit way a given knowledge domain. They are an «explicit specification of a conceptualisation» (Gruber), they «define basic terms and relationships» (Neches), «terms of domain structured in a hierarchical way» (Swartout). The role is to give explicit meaning to the concept avoiding the arbitrary attribution of meaning so that software agents can be helped in the creation of new relationships.

OWL provides constructs: classes (instances with homogeneous features) and properties (relations to describe a source). Object property is a relationship between classes; datatype property is between classes and literal.

The ontology somehow remains a subjective property that depends on our point of view: when we create an ontology, we have to create a reference document to understand classes, properties, rules of domain.

FOAF (friend of a friend) is one of the most used vocabularies. It is an ontology that describes people, relationships between people, information about people.

We can search reference documents online. They are readable by people and the authorised connections.

If a class has particular properties, these can be applied also to sub-classes.

The aim of the semantic web is the dissemination and creation of new knowledge, also allowing the reuse and/or adaptation of vocabularies and ontologies, always keeping in mind the open world assumption: information which is not true is not false, but unknown.

Thanks to ontologies, we can generate inference and combine information to create new knowledge (for example, if two people have the same parents, they are – by inference – brothers or sisters).

SPARQL (Protocol and RDF query language) is an interrogation language to explore information in RDF graphs and extract knowledge bases distributed on the web.

The representation of the query is based on triple and graph. They are always unambiguous identifiers. The triples are conserved in a database (triple store) through endpoint SPARQL. There is a box where an interrogation can be written.

Best practices ("Data on the web best practices, W3C recommendations", 31.01.2017):

(1) Use standards
(2) Use stable URIs
(3) Provide information about licenses
(4) Produce machine-readable data
(5) Overlook local peculiarities (or declare them in the metadata)
(6) Reuse vocabularies
(7) Provide up-to-date information
(8) Specifically, the reuse of data facilitates consensus in a community
(9) Interoperability

(10) Reduction of redundancy
(11) Elimination of ambiguity

Before modelling a new ontology, it is a good practice to see if someone has already done it or, at least, connect the new ontology to the already existing (and more used) one. This operation can be useful if the main ontology is not so used and may no longer exist in the future. If our ontology has been connected to that one, it won't lose meaning.

Sometimes dates are in a "literal" field. But if at least the year were transformed in URI, we would be able to link facts happened during the same year.

Cultural heritage (archives, libraries, museums) is a field where semantic interoperability is (or should be) widely used, in order to integrate different *corpora* of information.

As a result, enrichment, decentralisation and more control will be obtained.

The advantages are:

(1) Processing: machine-readable information;
(2) Discoverability: exploring and discovering new information thanks to links;
(3) Reuse: reduction of duplicated data;
(4) Trust: institute that adopts LOD becomes a trustworthy source;
(5) Linkability: continuous enrichment through links;
(6) Accessibility: fragmentation allows the exploration from different access points;
(7) Interoperability: every system can process in an independent and decentralised way.

Linked open vocabularies (LOV) allow us to search for existing ontologies.

Here are some examples of ontologies and publication projects:

Europeana is an aggregator of sources. It doesn't directly produce contents. It was created in November 2008. It is a digital library with digitised contents. Partner institutions send metadata of digitised objects to widen the search function and access to objects through links. The providers independently manage the data and send them to the aggregator.

Data are explored based on thematic areas: art, archaeology,…

It uses EDM = Europeana Data Model. Some items are taken up from the Dublin Core. It ensures the interoperability between ontologies and used models.

Problems = very high abstraction, high granularity; the producers themselves should send data to Europeana in LOD format. At this moment, Europeana has to convert them. It would be more decentralised and controlled by producers.

The *Biblioteca Nacional de España* has formalised its model. It proposes a new approach to materials such as bibliographical data.

The search function links information of that website to external information, for example a biography from Wikipedia, declaring the source.

Data are serialised in Turtle format.

Culturalis.org (cultural institution and site ontology) and *IBC*: dataset to describe subjects producers of archives. Other linked sources are OCSA (ontology of cultural organisations, services and access 2.0), EAC_CPF (descriptions ontology for linked archival data), OAD (ontology of archival description).

Culturalis vocabulary specification: also with explanatory graphs. Developed in 2012 and used for many different projects. Updated in 2018 to separate the objects of the description and its instantiation, so that every object can be linked to multiple descriptions.

The ontology eac-cpf has also been updated in the same way.

Ontologies can be used and combined with one another.

Yale Center for British Art: their dataset is linkable to external ones.

They use CIDOC. They also provide a SPARQL endpoint. I can search a work of art and get the complete description.

Possibility to export data in RDF format, to see how they are written according to the CIDOC ontology.

They use IIIF technology = International Image Interoperability

Framework. Different software applications that allow an easy dialogue between images.

The example of CIDOC CRM

CIDOC = conceptual model of the International Committee for Documentation starting from 1990. ISO standard in 2006, updated in 2014.

It is the wider ontology for cultural heritage. Widely disseminated for a thematic conceptualisation.

Exchange of information between heterogeneous sources.

All-encompassing, but, on the other hand, it loses expressiveness.

To describe all the domain of cultural heritage, I have to make use of abstraction.

It depends on the desired level of detail.

The attempt to keep everything together is a failure, but, thanks to LOD, I can refer to a higher model (for example CIDOC) and then describe local peculiarities with other ontologies.

The LOD lifecycle: from raw data to publication

Raw data and analysis > ontology (reuse and/or new) > data cleaning, production, publication (SPARQL), data cleaning, adaptation and interlinking

Raw data and analysis

Identify the domain that I want to describe

Identify the entities that are part of it

Analysis: which data do I have?

Analysis of the sources of origin

Ontology

Understand what I have (what I can reuse) and what I have to create: discussion with the domain expert

Concepts to represent

Assessment of the ontology

Useful tools = LOV = Linked Open Vocabularies: the creator of an ontology communicates it and it is published there. I can find all the classes and properties with a given prefix, with descriptions, comments, relationships.

Modelling choices: reuse (interoperability, discoverability, consensus), customisation (expressiveness, analyticity, independence).

A balance between the two approaches is recommended.

Production: how do I create URIs?

AGID guidelines = http://[domain]/[type]/[concept]/[reference_number]

Input can be an Excel table, a text file, an XML, an Access file

Transformation: rules are applied to translate documents, but they are not fixed

Output in RDF, N-triples, Turtle…

Publication

Triplestore: database that preserves the triples.

Endpoint SPARQL. In a default query, the command "select" defines which information is asked, "limit" limits the number of results, "where" defines a criterion of selection by specifying one or more triple patterns.

Adaptation and interlinking: it enhances the reuse of data.

C.
APPENDIX 3. SPEYER SYNAGOGUE RECONSTRUCTION: HANDOUT

TECHNIK
HOCHSCHULE MAINZ
UNIVERSITY OF
APPLIED SCIENCES

Handout for source-based 3D reconstruction of former synagogue in Speyer in 1250

Igor Bajena, Irene Cazzaro, Piotr Kuroczyński

2022

Introduction

The handout presents the methodology developed for the case study of the reconstruction of the former synagogue in Speyer in 1250 AD within the research project "DFG-Viewer 3D – Infrastruktur für digitale 3D-Rekonstruktionen"[11] and is a topic of interest of the Arbeitsgruppe Digitale Rekonstruktion (AG Digitale Rekonstruktion)[12] . The aim of this paper is to test scientific approach for documentation and publication of the source-based digital reconstruction.

Methodology

The proposed methodology for the digital reconstruction treats the 3D model as the result of scientific work, where all the choices that have been made during the process are accurately documented. This allows the preservation of the information behind the model and its evaluation. The final publication in the online 3D repository is thus vital for sharing the results and giving access to the scientific content carried by the model.

The different steps of the proposed methodology will be explained in the next chapters. They mainly include:

- The identification of the object;
- The collection of sources;
- Their classification according to their nature (photos in the location, archaeological reports and texts directly related to the synagogue, analogies with other buildings…);
- The creation of the structure of the model (identification of the hierarchy of semantical elements);
- The modelling phase;
- The documentation of the reconstructed elements;
- The publication of the results.

Assumptions outline

The first step is to draw up an overview of the assumptions for the reconstruction model of the object. Prepared description should

11 <http://dfg-viewer.de/> (accessed 04.11.2024).

12 <https://digitale-rekonstruktion.info/> (accessed 04.11.2024).

contains information about objects name, location, function and presents the object during the phase, which will be reconstructed. It should also cover the outline of the requirements, scope of development or level of detail applied to the 3D model. A good starting point for object description may be to check websites such as Wikipedia[13] or Wikidata[14].

Description made by Irene Cazzaro for the Speyer Synagogue in 1250 AD is as follows:

"The object of concern is the medieval synagogue of Speyer (in today's Germany), whose remains are still visible at the Judenhof, near the Speyer Cathedral. It is one of the best-preserved synagogues of the 12th century in Europe. Consecrated in 1104, the Romanesque building was then restored approximately in 1200 – again in Romanesque style – after a fire. In the second half of the 13th century it was renovated in Gothic style and a women's synagogue was built attached to it. The synagogue was the centre of the Jewish life until the 16th century, when, after several persecutions, only a few Jews still lived in Speyer. Our digital reconstruction takes into account the synagogue in 1250, thus during the second Romanesque construction phase. Some remains dating back to that time are still visible: the external walls, for instance, are still partially standing and in the western facade we can see two windows that are copies of the original Romanesque ones preserved in the Judenhof museum. It is assumed that at that time the walls, according to some small traces found on them, were covered with plaster. A portal was situated on the northern wall, whereas on the eastern wall the remains of an arch – part of the Aron Hakodesh – are still visible. There are no traces of the roof."

Outline of requirements for the same model made by Igor Bajena is as follows:

"The building should be placed in the middle of a flat fragment of terrain with dimensions of 25 x 25 m and a depth of 3.0 m and the depth of the foundations should be about 1.5 m. Some elements of interior equipment are excluded from the study. Modellers were

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13 <https://www.wikipedia.org/> (accessed 04.11.2024).

14 <https://www.wikidata.org/> (accessed 04.11.2024).

required to model an ideal version of the building, where geometry is based on the right angle, without any deformation. The main objective was to test the methodology and technical solutions rather than to imitate the illusion of realism."

The description should also consider the purpose of the model and what information it provides. It is also important to include characteristic information about the model, especially in the case when the same topic is reconstructed in several versions by different people.

Sources collection

Sources collection is fundamental for digital reconstruction. It can consist of many steps and can often evolve during the process enriching our reconstruction with new findings. Activities in this stage include photographic documentation of the location, visits to museums dedicated to the subject of reconstruction, searching for plans in archives, collecting articles, books and archaeological findings, and trying to find analogies, which can fill in the gaps caused by the lack of sources regarding particular elements of the building.

Other reconstruction projects carried out on the same object can also be an important element of the process. However, reconstruction projects are always marked by a certain level of hypothesis (uncertainty) and they should not be considered as the main source of the new research – rather they should be used to test new hypotheses. The assumptions made at the start of each project can affect its level of detail and development. This can mean that the same building, when reconstructed in different projects and with different constraints, can look very different.

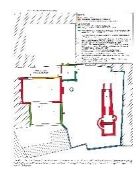
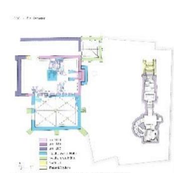
Photos

In the case of the synagogue reconstruction project, it was possible to successfully locate and prepare photographic documentation of both the remains of the building and the exhibits of the local museum (**FIG. 144**). A map with the location of each image has been prepared to make it easier for modellers to use the photographic resources (**FIG. 145**).

List of sources

The list has been elaborated during the SpSya_1250 project, together with Igor Bajena and under the supervision of Piotr Kuroczyński.

Archaeological reports

Provenance	Name of the file	Description	Preview
-	report_text.pdf	The entire text reports on the archaeological excavations carried out between 3 March and 22 June 2001 on the ruins of the medieval synagogue in Speyer by Monika Porsche.	
Archäologische Grabung 5. März 2001 – 22. Juni 2001 in der Ruine der mittelalterlichen Synagoge zu Speyer Abschlussbericht. Porsche, Monika.	report_drawing_01.jpg	Johannes Becker, Description of St. Free Roman Empire city of Speyer together with the four suburbs in 1773 [StA SP 1 aA nr, 895/1] Entry of names and dimensions in the cadastre on a scale 1:200 circumscription M. Porsche	
Information table on the site of the remains of the synagogue in Speyer	report_drawing_02.jpg	Plan of the synagogue distinguishing the different historical phases of the building by Monika Porsche and Pia Herber	
"Das mittelalterliche jüdische Erbe von Erfurt - Forschung und Vermittlung" Sczech, Karin, Stürzebecher, Maria. (2013) - In: Die SchUM-Gemeinden Speyer, Worms, Mainz S. 377-392	report_drawing_03.jpg	Drawing illustrating different construction phases of the building on the plan of the synagogue	
Archäologische Grabung 5. März 2001 – 22. Juni 2001 in der Ruine der mittelalterlichen Synagoge zu Speyer Abschlussbericht. Porsche, Monika.	report_drawing_04.jpg	Plan of the Synagogue in Speyer with	
"Das mittelalterliche jüdische Erbe von Erfurt - Forschung und Vermittlung" Sczech, Karin, Stürzebecher, Maria. (2013) - In: Die SchUM-Gemeinden Speyer, Worms, Mainz S. 377-392	report_drawing_05.jpg	Drawing illustrating different construction phases of the building on the elevation of the synagogue	

Photographs

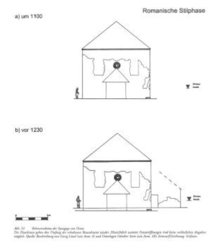
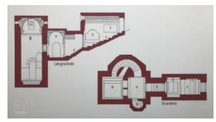
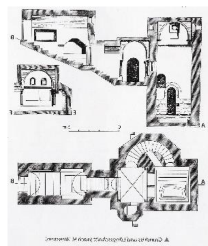
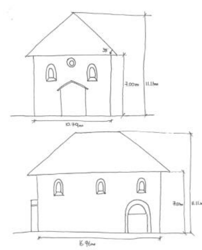
Author	Provenance	Date	Name of the file	Description	Preview
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_01.jpg	General view of the synagogue from North	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_02.jpg	General view of the synagogue from North	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_03.jpg	Synagogue – part of the external surface of the northern wall	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_04.jpg	Outer surface of the eastern wall of the synagogue (right) and the Frauenschul (left)	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_05.jpg	Synagogue - outer surface of the eastern wall	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_06.jpg	Synagogue - inner surface of the northern wall	

Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_07.jpg	Synagogue - part of the inner surface of the northern and eastern wall	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_08.jpg	Synagogue - inner surface of the western wall	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_09.jpg	Synagogue - inner surface of the western wall	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_10.jpg	Synagogue - detail of the inner surface of the western wall	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_11.jpg	Synagogue - inner surface of the eastern wall	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_12.jpg	Synagogue - part of the inner surface of the northern wall	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_13.jpg	Synagogue - inner surface of the northern wall	

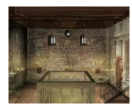
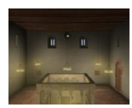
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_14.jpg	Synagogue - part of the inner surface of the southern wall (towards the Frauenschul)	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_15.jpg	Synagogue - part of the inner surface of the southern wall	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_16.jpg	Synagogue - part of the outer surface of the southern wall (from the Frauenschul)	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_17.jpg	Inner surface of the southern wall of the Frauenschul (left) and the synagogue (right)	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_18.jpg	Entrance to the Mikwa	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_19.jpg	Mikwa – detail of the vestibule	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_20.jpg	Mikwa - detail of the vestibule	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_21.jpg	Mikwa – shaft with basin from bottom to top	

Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_location_22.jpg	Mikwa – shaft with basin from bottom to top	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_museum_01.jpg	Physical remains of the western windows detached from the original structure of the synagogue and exposed in the museum.	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_museum_02.jpg	Description of the windows in "photo_museum_01"	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_museum_03.jpg	Floor tile from the Frauenschul	
Irene Cazzaro	Private collection of Irene Cazzaro	23.01.2022	photo_museum_04.jpg	Description of the three floor tiles from the Frauenschul exhibited in the museum ("photo_museum_03" is one of them)	

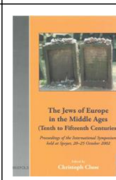
Drawings

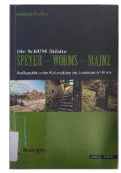
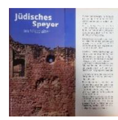
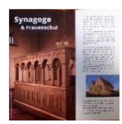
Author	Provenance	Date	Name of the file	Description	Preview
Christoph Engels	Engels, Christoph, "Gedanken zur Baugeschichte der mittelalterlichen Synagoge in Speyer", Pfälzer Heimat, 52 (2001), S. 61–72	2001	drawing_01.jpg	Sketches of the hypothetical reconstruction of the east elevation of the Synagogue in Speyer in 1100 and before 1230	
Based on the drawing by H. Weisstein, 1885	Panel found on the site	2022	drawing_02.jpeg	Section and plan of the Mikwe in Speyer	
Based on the drawing by H. Weisstein, 1885	Floss, Susanne, "Die Grabungen am Judenhof in Speyer 1965–1968: Die mittelalterlichen Befunde" (M.A. thesis, Universität Tübingen, 2005).	2005	drawing_03.jpeg	Section and plan of the Mikwe in Speyer	
Aliyah Mahmood	Archive of AI MAINZ. Sources used for the sketch are unknown!	2020	drawing_04.pdf	Sketch of the hypothetical reconstruction of the east and north elevation of the Synagogue in 1250 with dimensions	

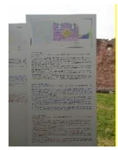
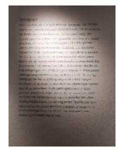
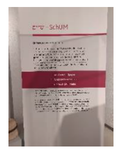
Reconstructions

Provenance	Source	Name of the file	Description	Date	Preview
“The medieval synagogue Speyer 3D computer reconstruction” by Architectura Virutalis with cooperation of the TU-Darmstadt	http://www.architectura-virtualis.de/rekonstruktion/synagogespeyer/pdf/2004_synagoge_speyer.pdf	reconstruction_01_flyer.pdf	Short presentation of the project "Die mittelalterliche Synagoge Speyer. 3D Computer Rekonstruktion".	2003	
	Private collection of Irene Cazzaro	reconstruction_01_rendering_01.jpg	Photo of the 2003 synagogue visualization banner in the building location	2003	
	http://www.architectura-virtualis.de/rekonstruktion/synagogespeyer.php?lang=de&img=0&file=0	reconstruction_01_rendering_02.jpg	Interior visualisation of the synagogue in the Romanesque phase – view 1	2003	
	http://www.architectura-virtualis.de/rekonstruktion/synagogespeyer.php?lang=de&img=9&file=7	reconstruction_01_rendering_03.jpg	Interior visualisation of the synagogue in the Romanesque phase with superimposition of a photograph of the current state of the building – view 2	2003	
	http://www.architectura-virtualis.de/rekonstruktion/synagogespeyer.php?lang=de&img=10&file=7	reconstruction_01_rendering_04.jpg	Interior visualisation of the synagogue in the Romanesque phase – view 2	2003	
	Uknown	reconstruction_01_rendering_05.jpg	Visualisations of the exterior of the synagogue in the Romanesque phase	2003	
Mainz – Worms – Speyer. Drei mittelalterliche Städte im Zentrum Europas als Linked Data	AI Mainz archive	reconstruction_02_model_01.pln	3D model of the synagogue reconstruction in Archicad format	2021	X
	23.01.2022	reconstruction_02_model_02.ifc	Model export to IFC format	2021	X
	23.01.2022	reconstruction_02_rendering_01.jpg	Screenshot of the synagogue model prepared for animation	2021	
	23.01.2022	reconstruction_02_rendering_02.jpg	Screenshot of the synagogue model prepared for 3D printing	2021	

Texts

Author	Title	Publisher	Date	Name of the file	Preview
Pia Heberer	„… war gezieret an den getünchten Mauern mit Gemählden“: Die Synagoge in Speyer. In *Die jüdische Gemeinde von Erfurt und die SchUM-Gemeinden: Kulturelles Erbe und Vernetzung*	Bussert & Stadeler	2012	article_01.pdf	
Monika Porsche	Villa Spira – civitas: Zwei mittelalterliche Judensiedlungen in Speyer? In *Zeitschrift für die Gesichte des Oberrheins*		2003	article_02.pdf	
	„Jerusalem am Rhein - eine Zeitreise vom Mittelalter bis heute“: Handreichung zur Nutzung der Materialsammlung im schulischen Unterricht und für außerschulische Projekte	Schumstaedte.de guidelines	2019 or after	article_03.pdf	
Igal Aviden	Jüdische SchUM-Städte am Rhein: Speyer, Worms und Mainz sollen Weltkulturerbe werden. In *Kultur Neu Entdecken*	SWR2 Leben	31.01.2020	article_04.pdf	
Falk Nicol und Diethard Walter	Ausgrabung und präsentation eines Mittelalterlichen ritualbades in sondershausen. In *Synagogen, mikwen, siedlungen: Jüdisches alltagsleben im lichte Neuer archäologischer funde*	Schriften des Archäologischen Museums Frankfurt	2004	article_05.pdf	
Pia Heberer	Mittelalterliche Synagoge in Speyer: Forschung und Rekonstruktion. In *Europas Juden in Mittelalter*	Herausgeben vom Historischen Museum der Pfalz Speyer	2004	article_06.pdf	
Ursula Reuter	Jerusalem am Rhein: Die SchUM-Gemeinden Speyer, Worms und Mainz. In: *Beiträge zur rheinisch-jüdischen Geschichte*	Eine Schriftenreihe - Herausgegeben von der Gesellschaft zur Förderung eines Hauses und Museums der jüdischen Kultur in NRW e.V.	2013	book_01.pdf	
Ed: Christoph Cluse	The Jews of Europe in the Middle Ages (Tenth to Fifteenth Centuries) *Proceedings of the International Symposium held at Speyer, 20-25 October 2002*	Brepols Publishers n.v., Turnhout, Belgium	2004	book_02.pdf	

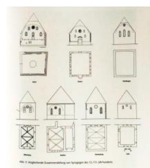
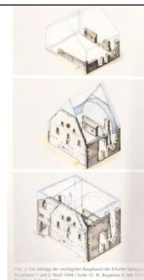
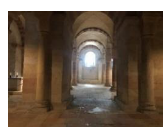
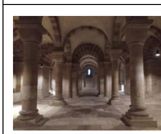
Eds.: Pia Heberer, Ursula Reuter	Die SchUM-Gemeinden Speyer – Worms – Mainz Auf dem Weg zum Welterbe	Schnell & Steiner	2013	book_03 (folder)	
Matthias Preißler	Die SchUM-Städte Speyer Worms Mainz: Ausflugsziele zu den Kulturstätten des Judentums am Rhein	Schnell & Steiner	2013	book_04 (folder)	
Georg Litzel	Description of the Speyer Synagogue		1759	description_01.jpg	
???	Die Ausstellung: SchUM am Rhein Von Mittelalter in die Moderne	Jüdisches Museum Worms Raschi-Haus	2021	flyer_01.pdf	
	Jüdisches in Speyer in Mittelalter	SchUM Museum Speyer		flyer_02.jpg	
	Synagoge & Frauenschul	SchUM Museum Speyer		flyer_03.jpg	
	Jewish life in medieval Speyer	SchUM Museum Speyer – at location of synagogue ruins		infoboard_01.jpg	
	The medieval "Jewish courtyard" and its buildings	SchUM Museum Speyer – at location of synagogue ruins		infoboard_02.jpg	

	The "Frauenschul" and other gothic transformations	SchUM Museum Speyer – at location of syangogue ruins		infoboard_03.jpg	
	The eastern wall of the synagogue	SchUM Museum Speyer – at location of syangogue ruins		infoboard_04.jpg	
	Eastern wall of woman's prayer hall	SchUM Museum Speyer – at location of syangogue ruins		infoboard_05.jpg	
	Synagoge	SchUM Museum Speyer		infoboard_06.jpg	
	Ein Verbund von drei Gemeinden	SchUM Museum Speyer		infoboard_07.jpg	
	Die mittelalterliche Synagoge in Speyer	SchUM Museum Speyer		infoboard_08.jpg	
	The Jews in Speyer in middle ages; The synagogue; Double arched windows	SchUM Museum Speyer		museum_labels _01.jpg	
	Fragment of round arch; Cushion capital; Pillar base; Three floor tiles	SchUM Museum Speyer		museum_labels _02.jpg	

Analogies

Sources related to similar buildings

Object	Provenance	Name of the file	Description	Preview
Eastern portal of the Cathedral in Mainz (Germany)	https://www.1000-jahre-mainzer-dom.de/rundgang/ostbau.html	analogy_01_01.jpg	Upper part of the portal	
Eastern portal of the Cathedral in Mainz (Germany)	https://www.1000-jahre-mainzer-dom.de/rundgang/ostbau.html	analogy_01_02.jpg	Detail of column capitals	
Eastern portal of the Cathedral in Mainz (Germany)	https://www.1000-jahre-mainzer-dom.de/rundgang/ostbau.html	analogy_01_03.jpg	Picture of the entire eastern portal	
Eastern portal of the Cathedral in Mainz (Germany)	https://www.1000-jahre-mainzer-dom.de/rundgang/ostbau.html	analogy_01_description.txt	Description of the object from the source page in German	X
Portal of the St Mary's Church in Great Bradley (Great Britain)	https://greatbradley.weebly.com/romanesque-architecture.html	analogy_02_01.jpg	Picture of the entire portal	
Portal of the St Mary's Church in Great Bradley (Great Britain)	https://greatbradley.weebly.com/romanesque-architecture.html	analogy_02_02.jpg	Detail of portal column base	
Portal of the St Mary's Church in Great Bradley (Great Britain)	https://greatbradley.weebly.com/romanesque-architecture.html	analogy_02_03.jpg	Detail of column capital	

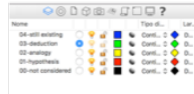
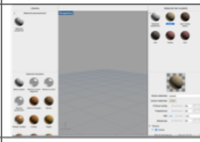
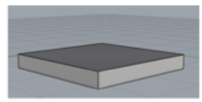
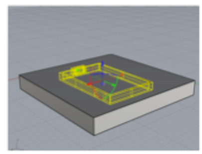
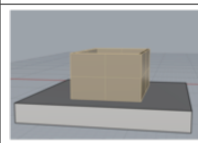
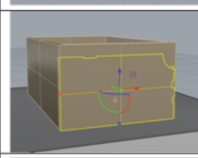
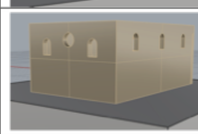
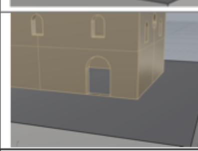
Portal of the St Mary's Church in Great Bradley (Great Britain)	https://greatbradley.weebly.com/romanesque-architecture.html	analogy_02_04.jpg	Detail of column capital on the other side of the portal	
Portal of the St Mary's Church in Great Bradley (Great Britain)	https://greatbradley.weebly.com/romanesque-architecture.html	analogy_02_description.txt	Description of the object from the source page in English	X
Portal of the Worms Synagogue (Germany)	„Perspektive Welterbe SchUM: Ein Managementplan für Speyer, Worms, Mainz - Bestandsaufnahme und Desiderate“ Heberer, Pia. (2013) In: Die SchUM-Gemeinden Speyer, Worms, Mainz S. 393-446	analogy_03.jpg	Historical photo of the portal of the Worms Synagogue in 1959/61	
Synagogues in Erfurt, Rufach, Nördlingen, Miltenberg, Maribor, Korneuburg, Tulln (Germany)	„Diaspora-Architektur: Synagogen im Kontext mittelalterlicher Städte“ Untermann, Matthias. (2013) - In: Die SchUM-Gemeinden Speyer, Worms, Mainz S. 283-296	analogy_04.jpg	Sketches of plans for medieval German synagogues from the late 12th and early 13th centuries. Particularly noteworthy is the shape of the roof, for which no sources are available for the Synagogue in Speyer	
Walls of the Erfurt Synagogue (Germany)	„Diaspora-Architektur: Synagogen im Kontext mittelalterlicher Städte“ Untermann, Matthias. (2013) - In: Die SchUM-Gemeinden Speyer, Worms, Mainz S. 283-296	analogy_05.jpg	Sketches showing the reconstruction of the missing elements of the synagogue's masonry structure based on deduction	
Crypt of the Speyer cathedral (Germany)	Private photos taken by Irene Cazzaro	analogy_06_01.jpg	The synagogue (topic of reconstruction) and the cathedral were built at the same time and by the same craftsmen. It means that we can use some of the elements of the cathedral to the reconstruction of the synagogue.	
Crypt of the Speyer cathedral (Germany)	Private photos taken by Irene Cazzaro	analogy_06_02.jpg		
Crypt of the Speyer cathedral (Germany)	Private photos taken by Irene Cazzaro	analogy_06_03.jpg		

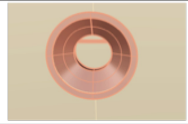
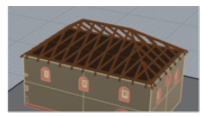
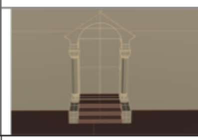
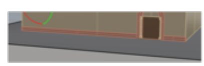
D.
APPENDIX 4. SPEYER SYNAGOGUE RECONSTRUCTION: WORKFLOW

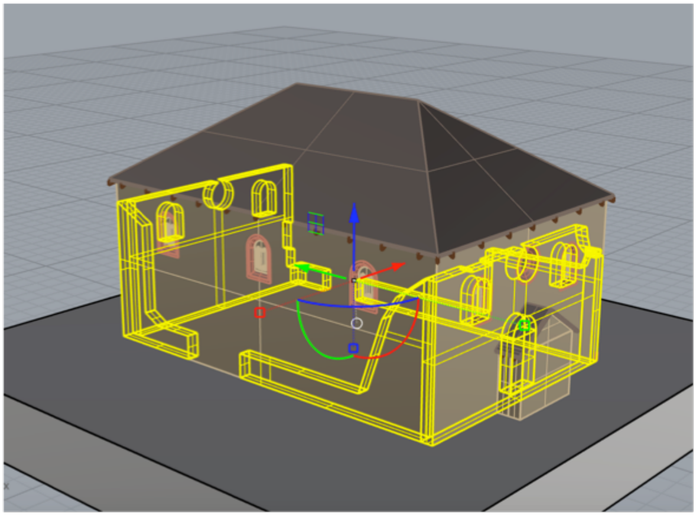
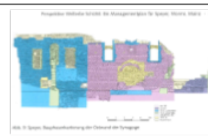
In the following pages are the documentation tables related to the reconstruction process applied to the Speyer synagogue (and, after that, to the other examples mentioned above).

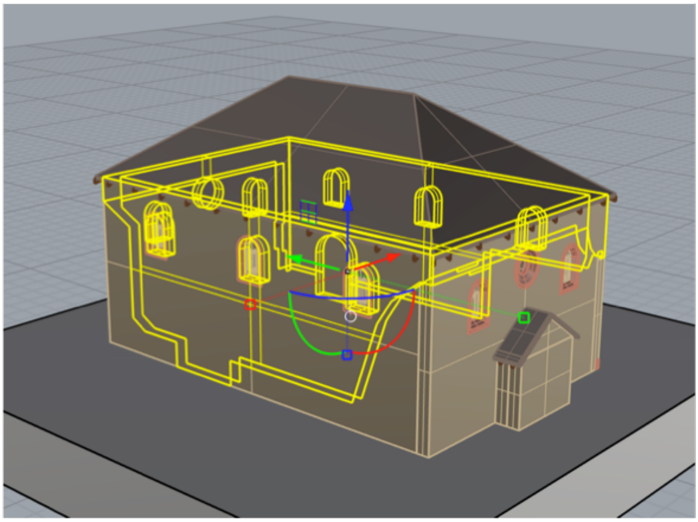
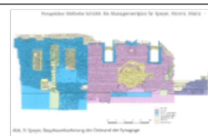
The first table traces the workflow that led to the creation of the model in Rhinoceros step by step; the other tables – one for each element as defined in the initial segmentation of the building – explain how each element has been reconstructed based on the available sources and their uncertainty level.

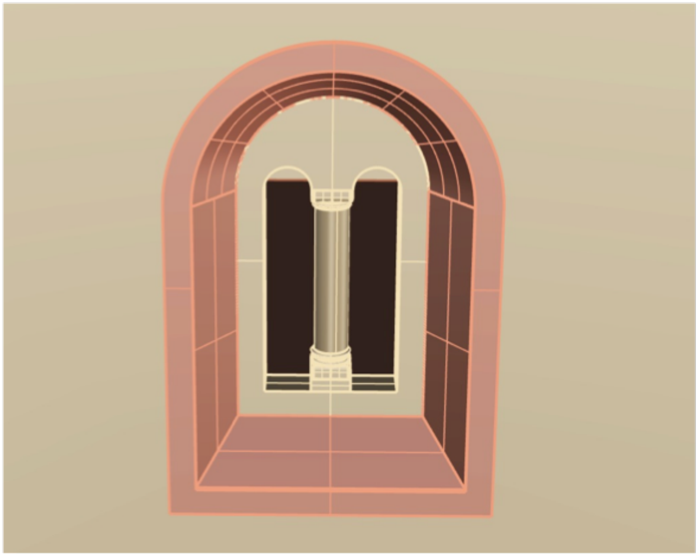
Workflow in *Rhinoceros*

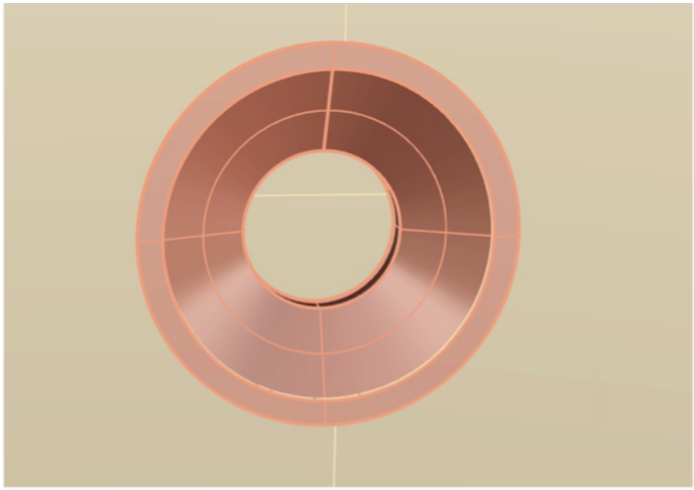
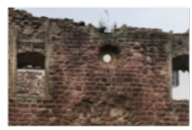
Creation of ***layers*** *for uncertainty visualisation: "04-still existing" (blue); "03-deduction" (green); "02-analogy" (yellow); "01-hypothesis" (red); "00-not considered (black)*	
Creation of ***object materials*** *and related visualisation* ***colours*** *according to the handout. The materials have been called "plaster" (texture_01); "frames" (texture_02); "floor" (texture_03); "door ceiling beams" (texture_04); "roof" (texture_05).*	
Basement *Obtained by extrusion (3 m) of a 25x25 m square* *Object name: "basement"* *Layer: "00-not considered"; colour: "by layer" (black); material: not defined.*	
Foundations *Obtained by extrusion of the related surface as in "report_03.jpg"* *Object name: "foundations"* *Layer: "04-still existing"; colour and material according to texture_01*	
Perimeter walls *Obtained by extrusion of the related surface* *Object name: "wall_2"* *Layer: "03-deduction"; colour and material according to texture_01*	
Subdivision of the eastern façade *Obtained by cutting "wall_2" according to the information in "report_05.jpg"* *Object name: "wall_1"* *Layer: "04-still existing"; colour and material according to texture_01*	
Holes for windows *Obtained by Boolean difference*	
Hole for portal *Obtained by Boolean difference*	
Floor *Obtained by extrusion of the area inside the perimeter walls.* *Object name: "floor"* *Layer: "01-hypothesis"* *Colour and material according to texture_03*	
"Bifora" windows *Obtained by extrusion and by rotation (columns)* *Frames obtained by extrusion and loft* *Object name: "window_1"* *Layer: "04-still existing" for those in the western façade; "03-deduction" for the other ones; colour and material according to texture_01 for the internal part and texture_02 for the frames*	

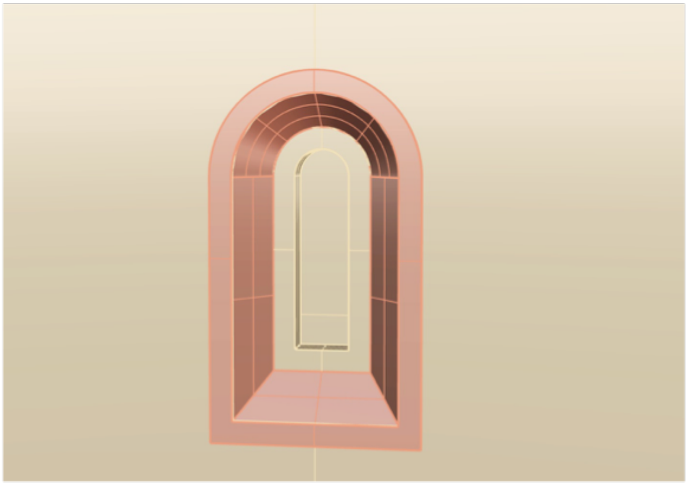
Circular windows *Frame obtained by extrusion and loft around the circular hole* *Object name: "window_2"* *Layer: "03-deduction"; colour and material according to texture_02*	
Arch windows *Obtained by extrusion* *Frames obtained by extrusion and loft* *Object name: "window_3"* *Layer: "01-hpothesis", colour and material according to texture_01 for the internal part and texture_02 for the frames*	
Portal *Some details are still needed. Mainly obtained by extrusion.* *Object name: "portal".* *Layer: "02-analogy"* *Colour and material according to texture_02 for the frames, texture_01 for columns and semi-circular wall above the door, texture_04 for the door*	
Beams *Obtained by drawing the rectangular section, extruding it for all the length of the beam that was then copied many times (some are horizontal, for the others the angle is 35°; the length varies according to the construction scheme)* *Object name: "beams"* *Layer: "01-hypothesis"; colour and material according to texture_04*	
Roof *Four surfaces with a 35° angle were created above the beams, then they were extruded* *Object name: "roof"* *Layer: "01-hypothesis"; colour and material according to texture_05*	
Aron Hakodesh – exterior *The walls were extruded according to the foundation. The roof follows the traces of the arch on the eastern façade.* *Object name: "aron hakodesh_exterior"* *Layer: "02-analogy"; colour and material according to texture_01 for the wall, texture_04 for the beams and texture_05 for the roof*	
Aron Hakodesh *Basement, stairs and upper part modelled by extrusion, columns by rotation.* *Layer: "02-analogy", colour and material according to texture_01 apart from the stairs, for which texture_03 is used*	
Plinth *Obtained by extrusion of a part of the wall.* *Layer: "03-deduction"* *Colour and material according to texture_02*	
Cornice *Obtained by extrusion of a part of the wall.* *Layer: "03-deduction"* *Colour and material according to texture_02*	

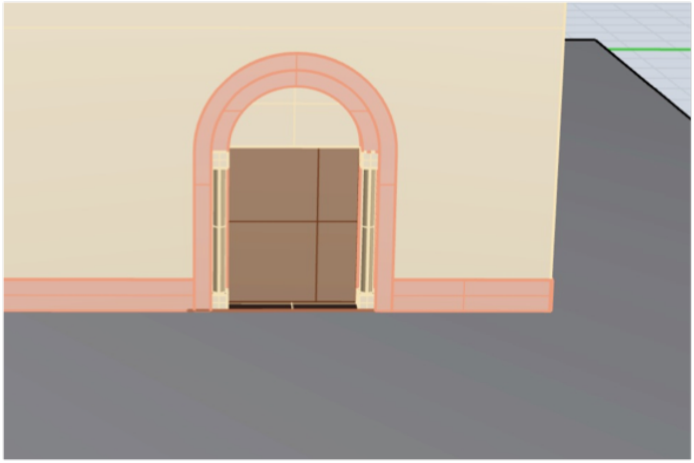
Wall type 1		
Reconstructed object		
Used sources	*report_05.jpg*	
	photo_location_01.jpg	
Argumentation and evaluation of the uncertainty	*This is the part of the wall that we can still see*	*04-still existing*

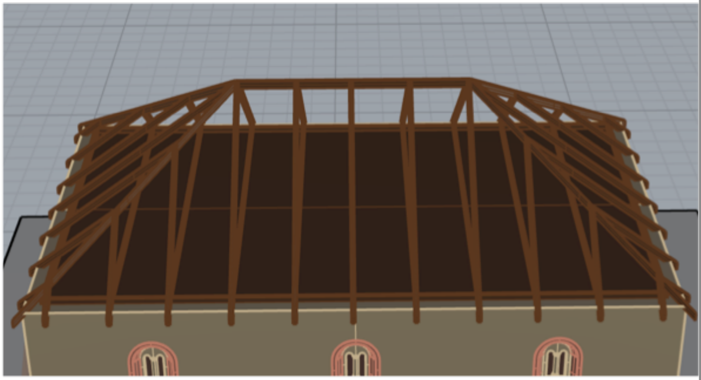
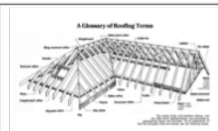
<table>
<tr><th colspan="3">Wall type 2</th></tr>
<tr><td>Reconstruction</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Used sources</td><td>report_05.jpg</td><td></td></tr>
<tr><td>photo_location_01.jpg</td><td></td></tr>
<tr><td>Uncertainty</td><td>This part of the wall was reconstructed by deduction, assuming that it was similar to the still existing part</td><td>03-deduction</td></tr>
</table>

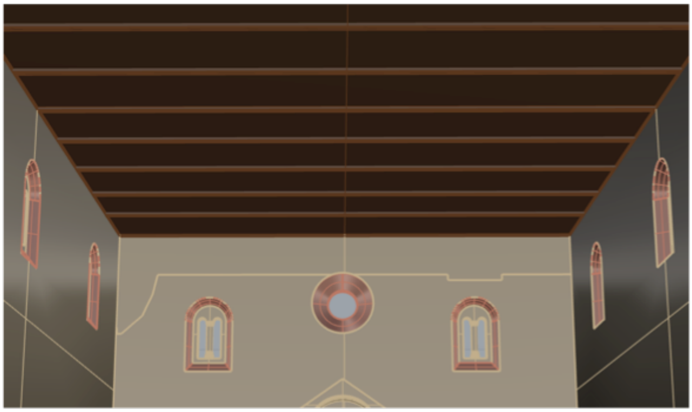
Window type 1		
Reconstruction		
Used sources	*photo_location_04.jpg*	
	photo_museum_02.jpg	
Uncertainty	*The windows on the western façade are copies of the original ones preserved in the Judenhof museum, thus in that case the uncertainty level is "04-still existing". It is assumed that the other windows were similar and can be reconstructed by deduction.*	***04-still existing*** *for those on the western façade;* ***03-deduction*** *for the other ones*

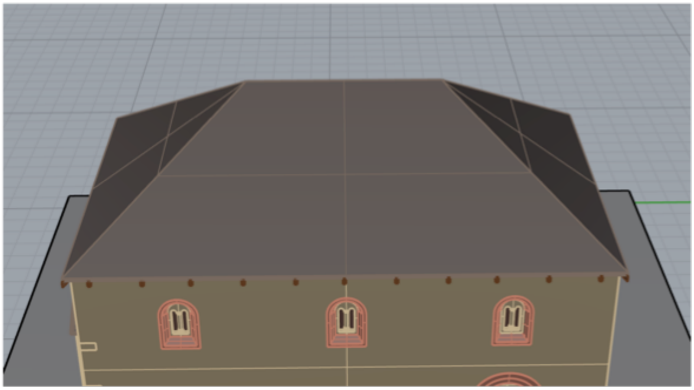
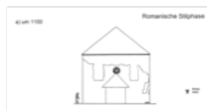
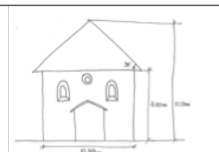
Window type 2		
Reconstruction		
Used sources	photo_location_01.jpg	
	photo_location_04.jpg	
Uncertainty	We can see the complete circular hole in the still existing part of the wall	04-still existing

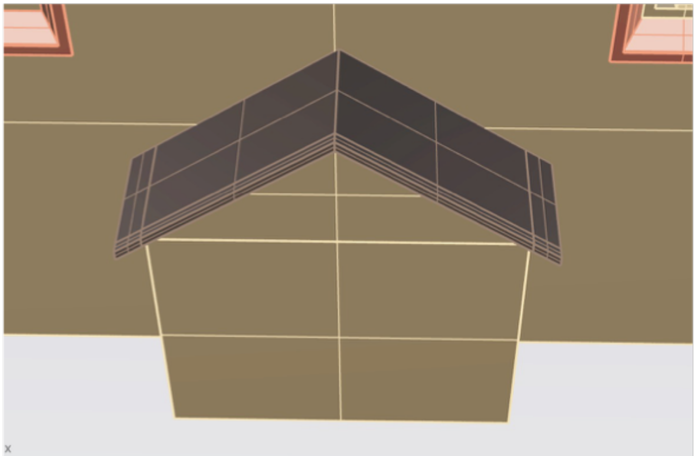
Window type 3		
Reconstruction		
Used sources	*reconstruction_01_rendering_02.jpg*	
	reconstruction_01_rendering_05.jpg	
Uncertainty	*We know nothing about the windows on the northern and southern façade, but there must be some source of natural light, maybe smaller than on the other walls.*	*01-hypothesis*

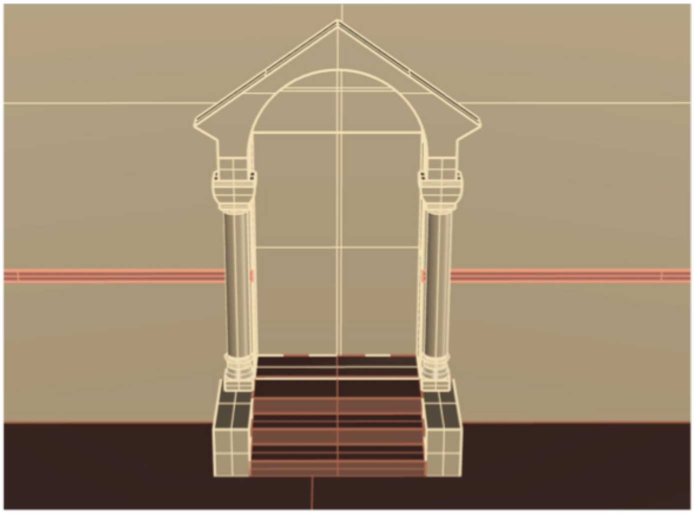
Portal		
Reconstruction		
Used sources	*analogy_02_01.jpg*	
	analogy_03.png	
Uncertainty	*We do not have traces of the portal of the Speyer synagogue, but we can reconstruct it by analogy e.g. with the portal of the medieval synagogue in Worms*	*03-analogy*

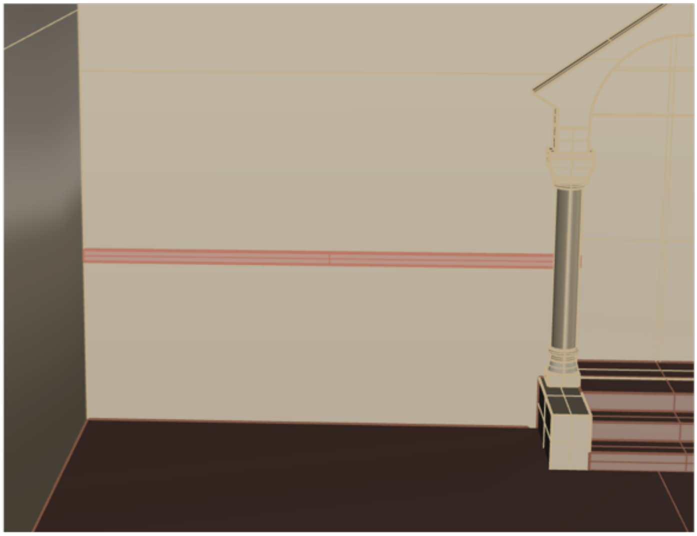
Beams		
Reconstruction		
Used sources	*https://s3.amazonaws.com/finehomebuilding.s3.tauntoncloud.com/app/uploads/1982/09/29111349/roof-framing-terms.jpg (accessed April 4th, 2022)*	
	reconstruction_01_rendering_03.jpg	
Uncertainty	*We know nothing about the structure of the roof*	***01-hypothesis***

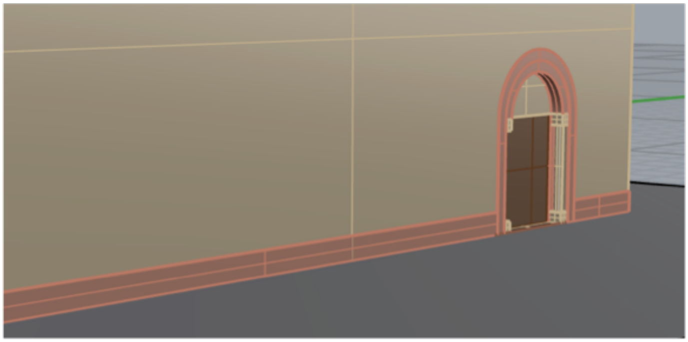
Ceiling		
Reconstruction		
Used sources	*reconstruction_01_rendering_02.png*	
Uncertainty	*We know nothing about the structure of the roof*	***01-hypothesis***

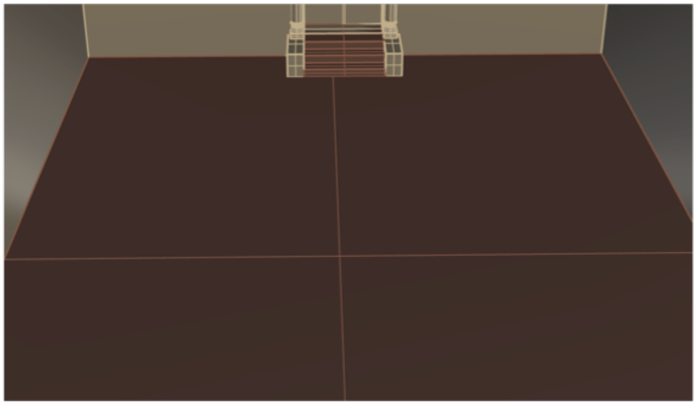
Roof type 1		
Reconstruction		
Used sources	*drawing_01.jpg*	
	drawing_04.jpg	
Uncertainty	*We know nothing about the structure of the roof*	***01-hypothesis***

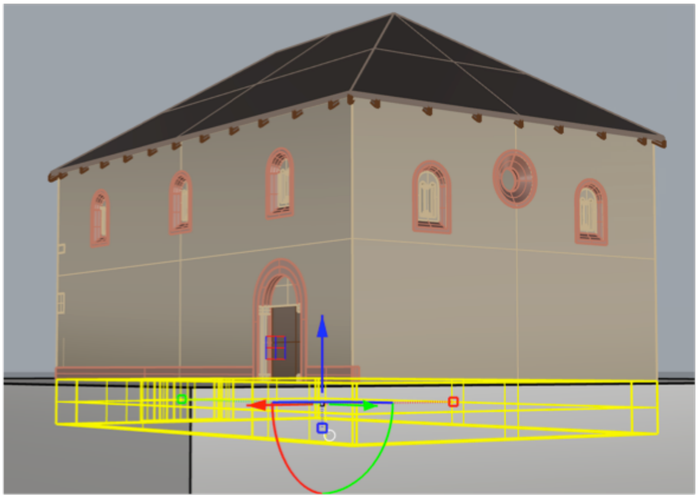
Roof type 2		
Reconstruction		
Used sources	*reconstruction_01_rendering_05.jpg*	 
Uncertainty	*We know nothing about the structure of the roof. The simplest thing to assume is that the slope of the roof is the same as the upper part of the Aron Hakodesh (this can be seen in the interior). The material is assumed to be the same as the main roof.*	*01-hypothesis*

Aron Hakodesh		
Reconstruction		
Used sources	*reconstruction_01_rendering_02.png*	
	Personal archive of Irene Cazzaro, who can make it accessible if required	
Uncertainty	*It was modelled based on similar examples of the same historical period.*	*03-analogy*

Cornice		
Reconstruction		
Used sources	*Personal archive of Irene Cazzaro, who can make it accessible if required*	
Uncertainty	*There are clear traces of it in the internal part of the wall*	*04-still existing*

Plinth		
Reconstruction		
Used sources	*reconstruction_01_rendering_01.jpg*	
Uncertainty	*There are some traces of the plinth, but they have to be mentally completed*	***03-deduction***

Floor		
Reconstruction		
Used sources	*reconstruction_01_rendering_02.png*	
Uncertainty	*There are no traces of the ancient floor*	*01-hypothesis*

Foundations		
Reconstruction		
Used sources	*report_05.jpg*	
Uncertainty	*The foundations are still there and they were analysed during the archaeological excavations*	*04-still existing*