Causes and effects

Methodologies used in digitalization of architectural-urban heritage

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Since some time already, digital reconstructions in architecture, urbanism and archaeology are gradually switching from describing built heritage as a collection of static and unchangeable entities towards more compound and explicit presentation and knowledge management techniques. This includes for instance data management and multimedia systems, immersive environments or semantic information modelling such as GIS (Geospatial Information Systems), BIM (Building Information Modeling) or HBIM (Historic Building Information Modeling). Graphical user interfaces, interaction and usability have become an essential part of produced reconstructions. This shift in terms of dissemination of an architectural and urban heritage that is supposed to increase the social awareness and participation should be structured in a way that enables recipients originating from different backgrounds to grasp information pertaining to almost any knowledge domain, allowing for self-exploration and interpretation of presented knowledge. This paper discusses important nodes of the reconstruction process in the spirit of informative modelling that are characteristic for any possible approach towards conscious heritage representations.

Keywords: Informative modelling, Spatio-temporal modelling, Cultural heritage

CONTEXT

In the field of architectural heritage the objects that researchers are striving to reconstruct are never fully known. The incontestable fact is that they do have a rich and usually complex history, abundant with evolutions and changes. These changes are usually understood only in terms of their topology and morphology as the physical appearance stresses the process. Yet the alteration does not affect only the artefacts materiality. Immaterial aspects of the site are affected by time passage and events not less. Elusive cause and effect factors that were influencing the entities determining their shape, condition, location or characteristics should be taken into consideration as well. There is a strong need to preserve space for uncertainty as well, as hardly any heritage unit is free of doubts emerging from, for instance, heterogeneous, dubious, incomplete or even contradictory historical documentation - if any in the first place. Furthermore urban, as well as architectural entities are never constant in time as they tend to undergo constant and unavoidable transformations of different types.
throughout their lifespan. These events in combination with plurality of factors that may seem divergent or even unrelated at the first glimpse, shape and form the buildings or whole urban complexes through their lifecycles. Moreover, the typological difference between architectural and urban entities, which results from the fact that the urban environment can be perceived as a container for multiple architectural components, awakens the awareness of different granularities - or scales - of aforementioned causative factors and events. Better or worse preserved remnants of architectural past encountered nowadays are therefore resultants of all these processes that had occurred. Amalgamate of these factors can be eventually perceived as the construct of what could be called the meaning of the built artefact.

INFORMATIVE MODELLING
Complex, multi-layered network of intersecting elements and types characterizing architectural artefact requires adaptive representation model. In the domain of architectural heritage gathering, analysing, structuring and understanding various types of source documentation is the fundamental part of the process, whereas visualizing and retrieving information is the paramount aim of each. Therefore information visualization - where the 3D representation of an architectural entity serves only as a perceptive tool and does not constitute the final result of the reconstruction process - seems to more accurately fit in the general idea. This was summed up precisely by E. R. Tufte and J. Bertin who said respectively that: “We envision information in order to reason about, communicate, document and preserve that knowledge” (E.R. Tufte 1997) and “...a graphic is never an end in itself: it is a moment in, a process of decision making...”(J. Bertin 1967). This is already the basis of the interdisciplinary methodological approach - or concept - of an informative modelling in which the representation of artefacts does not claim veracity, but supports dynamic information retrieval and visualisation, reasoning and cognition. Abstraction (the information visualisation legacy) and figuration (the architectural representation legacy) are integrated as alternative/mixable types of representation, allowing partial knowledge to be communicated and important notions in historic sciences such as data uncertainty to be conveyed graphically. Though artefacts’ accurate and precise representation is not determined, present advancing data-processing technologies allow for more comprehensive and massive data acquisition from heritage sites. These become necessary in order to describe, understand and support built heritage. Moreover developing software technology allows to combine models acquired during high definition surveys with the informative layers, as well as to adopt them for logical re-use in various, process depending scenarios. Nevertheless the veracity of the model remains still in question as the dense point clouds need to be discretised into more efficient and reuse-ready meshes or polygons. This in turn demands simplification of the acquired data set, which results in some level of divergence from the original. (Figure 1) Authenticity of the model is however, out of the question when we discuss models constructed solely on the basis of existing historic documentation, which fundamentally must be treated with caution and cannot be taken for granted.
**BI-DIRECTIONALITY**

With progressive advancement of information technology more and more options to store, manage and present acquired datasets are available for the researchers. Nevertheless it occurs to the author that it is currently possible to determine two particular directions in which the process of digitizing built heritage is heading. The foundation for this specific bi-directionality lays on the one hand in the development of BIM theory into practice which results - from a CAD (Computer Aided Design) point of view - in the release of dedicated specific software such as Autodesk Revit or Graphisoft Archicad, as well as proliferation of its assumptions through diverse groups of interests such as architects, archaeologists, historians - to name a few; and on the other hand in the need to search for and create custom solutions dedicated to particular problems or issues, which is strongly encouraged and motivated with the spread and popularisation of programming languages and highly advanced frameworks such as Unity 5 or Unreal 4 engines which from some time already are no longer reserved only for a top-end professionals or AAA development studios. While both approaches are conceptually different they try to serve the same purpose: to gather, manage and disseminate the knowledge about built heritage.

**OUTSET**

Regardless of which approach is to be chosen finally, there are still some strategic decisions to be made and steps to be fulfilled initially. This article aims to describe them in more detail. It highlights three factors that are fundamental for the reliable organization of such a complex multidimensional reconstruction model: addressing temporal issues, spatio-temporal representation of uncertainty in data, hypotheses and a spatial organization of the model to allow diverse usability. Source data handling is not going to be included in this paper as this particular matter rather depends on their quality, quantity, type and specific purpose of undertaken reconstruction process. Therefore its management and treatment may vary and be performed in too many different ways using multiple approaches exclusively or in parallel.

**THE OCCURRENCE OF CHANGE**

As it was already mentioned, every built entity changes during its lifespan. Number of possible transformations it could go through are vast, though it is possible to distinguish most relevant: buildings are built, destroyed, rebuilt, they may be extended, attached to another entity or divided into several parts. Eventually they can peacefully degrade through the whole life-cycle. Last but not least it can occur that the building would be totally or partially erased and rebuild in the same or different location (e.g. city of Warsaw after II World War). This statement makes apparent that whenever there is a change in space (spatial alteration) it never happens instantly but instead implies that some time passed from the beginning of transformation to its end. Undeniably time plays an important role in the description of change. Even more when we take into consideration that not only spatial form of the building is changing but also its relationship with surrounding entities or its particular attributes. Reassuming, the change can affect objects morphology, topology or attribute definition and it never lacks a temporal dimension. (Figure 2) The time of each alter-
ation is, as a matter of fact, never constant. Each type of change lasts different amount of time. For example the demolition of the building can take just a few days, while its construction could last for years or even decades. This implies that time of the event occurrence is therefore scalable, which means that temporal incidents have different granularities. Such complex spatio-temporal transformation system occurring on different - usually nested - levels with various scales need a proper and suitable data management system. Pelekis (Pelekis et al. 2004) described and compared eleven ready-to-adopt database models with various levels of complexity, each accurate for certain tasks and aims. The question of which model to choose relies mostly on the defined goal of the undertaken reconstruction, its intricacy, query structure and operations it should be capable to perform simultaneously. Whereas some models are simple and operate on the snapshot or time-stamping based structure (Figure 3), others reflect quite elaborated mechanisms derived from graph theory (Figure 4) or Object Oriented Programming (Figure 5).

**UNCERTAINTY IS WHAT REALLY MATTERS**

In the domain of digital heritage a lot of effort is put to create accurate and precise digital reconstruction models from available spatial data, preferably using Terrestrial Laser Scanning or photogrammetry techniques supported by historic documentation. Simultaneously it limits the scope of the reconstruction to the digitalisation of only what is left or, perchance, to particular states of the building to which available documentation does not arouse any level of uncertainty or suspicion. However, in the field of architectural heritage, more than anywhere else, due to its unstable and long-term character, not only spatial, but temporal aspects need to be taken into consideration. Traces in form of historic documentation stored in archives (if there are any in the first place!) are rarely satisfying the researchers. Heterogeneous, dubious, incomplete or even contradictory documentation leaves many question marks and door open for hypothesis and introduces the possibility of uncertainty concerning spatial, as well as temporal or even attributable aspects.

Spatial uncertainty results usually from lack of material on which the researcher could base the reconstruction. Historic sites were rarely, or never, surveyed in the past when no one would expect them to be historic one day. Most of the archived material consists usually of crude designs and drawings, but almost never of post-construction surveys. This
makes researchers working with almost hypothetic source documentation, as the changes made on-site during construction of the building were, with the high level of probability, never marked or described. Researchers are usually left with pieces of information on which they are supposed to build their proverbial church. As it is impossible to find just one ideal solution that would describe changing building morphology it is crucial to refer to the hypothesis based on reliable sources not necessarily concerning particular entity but at least similar from the same time period. Temporal uncertainty, on the other hand, is even more complex and can be described with several factors. First, and probably one of the most important, is the problem of dating exactness, which reminds instantly about time scale and granularity. Events which took place in XIXth century, in year 1845, between the year 1897 - 1909 denote different temporal weights. If the scale is the century - is there a possibility to define the year precisely? Or if the scale is the year - is it possible to define the month? This imprecisions in dating description causes lack of cohesion and presents first important technical problem as well - which constitutes the timeline and event positioning. Another trouble arises with the interpretation of the heritage sites. The past is usually interpreted by different kinds of historians (the historians, art or architecture historians, etc.) on the basis of available historic sources. This can undoubtedly lead to a formulation of various and divergent interpretations - or rather - hypotheses concerning particular entity, site, event or period of occurrence. As a result each formulated opinion is laden with some level of uncertainty, even despite the purest intentions of the interpreters, which in turn affects the entity and possibly distorts its spatio-temporal change pattern deviating it from unfortunately unknown reality. Realising the potential of the stratified uncertainty could leave us with the thought that the only real and certain element of spatio-temporal reconstruction chain is the existing residue of an object and that every attempt to model its past state is resulting in creating just a hypothesis.

**STRUCTURAL SYSTEMATICS**

To entirely utilize the potential of building entities for the sake of performed reconstruction it is necessary to classify them in order to withdraw maximum spatial information from general data. It is possible to distinguish three phases of such ordination. First one assumes classification according to the adopted point of view - which means distinguishing elements according to their e.g. function or material they are composed of, as well as to other criteria such as a time of erection or style they were built in, etc. Second differentiates elements according to their morphological decomposition in the life-cycle process. Eventually, in the third phase associations among concepts are created and visualized. Working with historic structures requires constant reasoning about temporal changes. This in turn necessitates proper model structuring and reorganization which leads to the question of its morphology as well as its attributes and spatial relationships with surrounding entities. Recalled earlier, the concept of granularity, has a strong influence not only in case of temporal dimension but spatial and structural as well. Each building undergoes changes, but each one is a composition of parts which, as a matter of fact, also undergo change. Accordingly, this works in opposite direction: a building is just an element of a larger group of buildings which in turn constructs a neighbourhood, district or town. Therefore it is possible to introduce various levels of spatial granularity as well. Defining this hierarchy is important, as every element or entity would have its own specific attributes, sometimes utterly unique, sometimes shared with others. In general it is possible to organize objects in three nested levels: groups - agglomerating building complexes, single buildings and their major components; entities - corresponding to the functional and temporal model divisions; references - representing some specific aspects of extracted entities. This peculiar morphological inception could be than limited by setting the minimum and maximum level of detail that seems sufficient for the purpose of performed reconstruction.
CONCLUSION
The society of information we are currently experiencing, demands an informative, scientific approach to each and every aspect of life. This is particularly valid and important in the domain of architectural heritage, which is built on the knowledge of the past. Therefore the number of methodologies or approaches to the matter of architectural-urban reconstruction processes seems fairly limited, as no matter what, any of them would revolve around the idea of creating a knowledge management system concerning the heritage entity. Research performed for this paper revealed that all analysed case studies did encounter particular problems while conceptualizing systematic workflow. Spatio-temporal data management, insufficient sources that provoke and fuel uncertainties related to spatial, temporal, as well as attribute layers, handling of existing hypotheses are mostly reported. Therefore the gravity centre of this article was moved a bit from depicting methodologies towards describing these specific challenging nodes that in the same time determine the structure of informative reconstruction model. Description and potential guidelines for handling such cases were formed on the basis of available literature. Application of these nodes in the process of reconstructing architectural or urban entities of different scales seem valid and critical for implementation either in BIM driven reconstruction models or custom-made solutions.

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