PROFILING ARTEFACT CHANGES: A METHODOLOGICAL PROPOSAL FOR THE CLASSIFICATION AND VISUALISATION OF ARCHITECTURAL TRANSFORMATIONS.

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ABSTRACT:

When studying heritage artefacts and trying to represent what we know of them, it is important to portray not only key moments in evolution of artefacts, but also processes of transformation. In this contribution, we introduce a methodological framework of description of artefacts' transformation and investigate the usability and efficiency of diagrammatic representation as a mean to visualize the above mentioned framework. A focus of our interest is the way artefacts get transformed. The methodological proposal presented identifies as a central notion: a *life cycle* - a sum of states and transitions following in succession- in what can be seen as a diachronic approach. We then introduce the diagrams proposed in order to visualise the above mentioned life cycles and provide examples on major or minor architecture within the medieval part of the town of Kraków (former capital of Poland, experimental set for this research). Two types of diagrams are introduced: *diachrograms* that distribute along a time axis transitions and states, and *variograms* that detail the nature of the changes. A combination of these graphics should help better understanding, in a cleat-cut manner, how changes over time affect architecture. But it should also underline key aspects of data in "historical sciences": uncertainties, incompleteness, long ranges of time, unevenly distributed physical and temporal stratigraphy.

1. INTRODUCTION

1.1 General objective

Heritage artefacts, may they be individual edifices or whole sites, are rarely left unchanged by time. Various natural or man-related events occur throughout the centuries, resulting in numerous transformations. Such transformations can introduce minor architectural changes (extension, refurbishment, change of usage) or cause important modifications, both in terms of physical appearance and in terms of usage. Ultimately, what today we observe (the artefact itself) and know (historical analysis) can be understood as a collection of traces, traces of all the moments an artefact has been through during its often complex evolution. Methods exist that help researchers to state (although with remaining doubts) how an artefact has been at time t_1, t_2, …, t_n. Broadly speaking, such methods rely on "expert-interpretation" of observations or archival data. In addition, when possible, they can include cross-examinations of individual cases considered as similar on one or several aspect. But if one wants to represent and explain the processes that lead from state at time t_1 to states at time t_2, …, t_n, less solutions exist. As an answer, we investigate diagrammatic visual displays, that could foster a comparison-enabled, global vision of an artefact's evolution; whereas traditional architectural representation (CAD based or not, see (Estevez, 2001), by privileging shape modelling, tends to enhance states over changes. In other words, we here experiment the infovis path – amplify cognition (Kienreich, 2006), rather than the scientific visualization path – real object/graphics mapping (Spence, 2001).

Given an efficient, workable, identification of states and transitions, synthetic diagrams could offer an unprecedented view on the global evolution of an artefact. In addition, such graphics could possibly uncover patterns of evolution within a site or across sites, underline uncertainties or exceptions ("documentary gaps"), raise questions about the relative evolution of families of artefacts (urban houses in this or that quarter of the city, churches across the city, gothic castle across a wider territory, etc.). Accordingly, our objective is at the intersection of two issues:

- a methodological framework enabling the description of architectural changes (*i.e.* a knowledge modelling issue),
- a set of visual signs and/or diagrams developed in order to apply (and evaluate) the above mentioned framework on real cases (*i.e.* an infovis issue).

In this paper we will focus on the former aspect, with the latter used as a mean to evaluate it on real cases.

1.2 Context and background

When studying heritage architecture, the heterogeneous nature of documents handled poses a number of problems (*i.e.* ambiguity of textual descriptions, exactitude of artistic representations benefiting largely from *licencia artistica*, etc.). A resulting interpretation is drawn from the reading of a historical source, as well as from the experience, knowledge and intuition of the analysts. The result of this process is a hypothesis. In "historical sciences" however, one cannot use experiment in order to verify a hypothesis (an experiment in the past is not very realistic!). Therefore the only way to amplify a validity of a hypothesis is to confront it with unknown data or with the results of other scientists (*cf. intersubjectivity* (Bocheński, 1968)). However such cross-examinations should go beyond a parallel reading of states, and include an analysis and visualisation of causes and effects. Now, when analysing major current research axes, one can observe that *synchronic* approaches are strongly dominant.

Renewed survey techniques, simulation through 3D modelling and virtual reality, site management systems using GIS platforms, archival information systems are among the most prominent results, with at the end of the day a number of clues related to one or another moment in the evolution of an artefact.
On the "computer graphics and/or new technologies" side, various spatial granularities are observed (ranging from cities (Lerma, 2004) to architectural interiors (Perkins, 2003)). However, in the above mentioned field, architecture has served mainly as a test bench -here for immersive platforms, there for 3D surveying, etc.. A good example can be found in (Suverg, 2003) where urban architecture, illustrating a research on geometric reconstruction, is described only through three parametric building models called primitives: flat roof, symmetrical gable roof building, nonsymmetrical gable roof building (sic!). Another typical example is the use of VR for site presentation (Ando, 2003) where architecture finally appears as a context-free phenomenon, with a still-image of the edifice giving no hint on why, but unduly portraying a moment in the past (for which we have no such certainty as the image suggests). In the above examples, architecture as a domain is widely ignored, and the scientific conclusions would have been the same if scientists had studied ship containers, kennels, rabbit warrens, etc..
On the "humanities" side, a strong investment has been done in the past decade on computer-aided data recording, analysis and management (see (Müller, 1997), (Ramondino, 2001), (De Luca, 2005)), with common applications ranging for instance from expert-oriented archaeological site management (Sebillo, 2003), (Huber, 2000) to didactic end-user visual disposals (Kodym, 1999), (Kantner, 2000), (MhMK, 2007). But here again, the effect of time and events (that of course researchers are very aware of) is far from being stressed.
As can be seen from these examples, the focus is ultimately put on describing specific (and chosen) moments in the life of an edifice or a site, may this moment be contemporary (surveys, site management), or may it be time t_n of the artefact's evolution (3D reconstruction, documentation and archive studies).Very little has specifically been done, in the field of the architectural heritage, in order to describe and represent visually the time-chain between successive states or moments in the evolution of artefacts. However such approaches can be found outside of the field of the architectural heritage, and in particular in geography. Time-geography (Lenntorp, 2003) is typically an approach where the focus is put on time motion. Still, time-geography applies to spatial concepts that do not match the granularity one faces in architecture. Moreover, time geography applies mainly to short life cycles, where the global spatial context (inside which the variations over time of a phenomenon are studied) remains unchanged.
A much closer example can be found in graphs proposed in (Renolen, 1997), where changes in land areas are visually assessed through synthetic, easy-to-read diagrams. Renolen describes and represents territorial changes: he isolates states and defines events causing changes, a view that we base on. However, his field of application is land areas as seen by a geographer, and the graphs proposed are not directly from being applicable to architectural changes. Among noticeable differences are the 3D nature of artefacts, the transformation processes within a given and stable land area, the reuses and displacements, long-term internments of built structures, uncertainties and incompleteness in the data sets, in the dating of events, in the actual physical transformations, etc..
In this paper, we develop an analysis of states and transitions that we believe better matches the specificity of heritage architecture.

2. IDENTIFYING CHANGES

2.1 Terminology

In order to avoid misunderstandings, it is important to define the two set of terms we will be using. To start with, we need to point out differences between the artefact as a whole and its possible remaining sub-parts once transformed (Table 1).

artefact	an entire object or ensemble considered as one basic entity
portion	a subset of an artefact resulting from its conceptual division into an active part (a core object) and an inactive part (a segment)
core object	an artefact's main portion, *i.e.* - generally an apparent superstructure along with its active substructures, - possibly an inaccessible substructure when the apparent superstructure is demolished, - possibly, a substructure when the artefact was designed as a substructure from the start.
segment	a distinct, underground and inactive portion of an artefact

Table 1. Naming of the artefact and its sub-parts

We also need to make clear what we consider when talking about an *evolution of an artefact*, in comparison with what we call a *life cycle*.

- An ***evolution of an artefact*** is a process of gradual development of an artefact over a whole period of its life, from its creation until its extinction (*i.e.* its thorough and irreversible physical removal, including of sub-structures, or its division) or - if the artefacts still exists - until today.
- An ***artefact's life cycle*** identifies a time slot corresponding to a fragment of artefact's evolution. A time slot during which all transformations are partial (*i.e.* the artefact is neither moved nor entirely subdivided into new independent structures, its superstructure – if it had any - remains in elevation).

Given the above definitions, an artefact's evolution may therefore contain several cycles of life. Good examples of this are Roman villas in the site of Pompeii, buried for centuries after the eruption of the Vesuvius. These villas have had (at least) three cycles of life: before the eruption, while buried (centuries below ashes), and since they have been uncovered by archaeologists and opened to visitors. Understandably, life cycles are then tagged as primal (first cycle after creation) or recurrent (others), simple or compound (if inactive substructures called segments exist underneath the artefact), and their sum marks the evolution of the artefact.

2.2 Two main notions: states and transitions

Each ***life cycle*** can consist of a number of ***states*** and ***transitions***. States are occupying time slots during which no major transformation occurs (or should we say when we have no indication that such transformations occurred). In other words, states identify periods of stability. Each state is preceded and concluded by transition(s) - time slots during which transformations occur. Often enough, transitions in the field of the architectural heritage may be rather long-lasting (*). Transitions indicate that a process of transformation is under way, with specific indications that underline possible causes (for instance, damages caused by fires, a common plague during the medieval period).

To sum it up, one can see transitions as causes, and states as consequences. Accordingly, their descriptions will naturally vary. In the next sub-section, we briefly introduce both states and transitions, and illustrate them by giving examples among which some are well-known artefacts or sites.

2.3 The tables of states and transitions

In this section we provide descriptions of states and transitions. Transitions and states may share the same tag: tags identify either the processes themselves (within which changes progressively occur, between a start date and an end date) or results of these processes (once changes denoted by the tag cease to occur). Typically, a decay transition starts when a first part of roof falls and ends when no roofing is left. The decay state then identifies the result of the decay transition: an artefact with no roofing, irresistibly degrading if nothing is done.

The tables contain a tag's name, its definition, and examples that should illustrate the semantics behind states and transitions (formatting presented below). Tags are ordered alphabetically.

tag	definition
example	

abandon <transition> [state]	Progressive withdrawing of a human activity, but artefact remains covered.

A medieval fortified village of Rougiers, erected on a hill 650 m over plateau, in 1760 became definitively abandoned by its inhabitants, who since XV century started to move to live on the plateau.

annexation <transition>	Combining/incorporating an artefact or its portion into another artefact. The life cycle of the annexed artefact (or portion) ends, while the annexing artefact continues the same life cycle.

Once the ensemble of Collegium Maius (Kraków) became a university (see transition "merge" below), it was further enlarged by acquiring new additional properties and integrating them into the existing ensemble. Annexed houses ceased to exist as independent artefacts, and became parts of the annexing ensemble.

decay <transition> [state]	A gradual degradation of an artefact due to absence of human activity and destruction of roofing.

It usually takes years for a building to loose its roofing (see for instance the Tivoli site).

demolition <transition>	A relatively quick destructive incident, caused by environment or human activity.

A Gothic town hall of Kraków was partially destroyed by fire in 1570 and 1680 and than renovated. In 1820 a main building of the town hall was demolished during a destruction of an adjacent building of granary. Only a tower and underground structures survived.

Kraków, town hall and granary before 1820

modification <transition>	Each significant functional, structural or morphological change inside one life cycle. This is naturally the most common transition.

The Louvre ensemble in Paris is the result of a number of modifications, either functional (at start- a defensive medieval castle, now- a museum) or morphological (medieval keep, classical and neo-classical galleries, contemporary sub-structures).

secession <transition>	A division of the artefact with a separation of one or several portions, leading to the creation of independent artefacts. The rest of artefact continues it's life inside the same life cycle.

A town hall of Saint-Maximin is a Neo-Classical edifice that belonged to Gothic monastic ensemble. In the beginning of XXth century it was separated from the monastery. Today it has nor functional neither morphological continuity with the rest of the monastic ensemble.

segmental anaesthesia <transition> [state]	Loss of all functional activity and of connexion with the rest of an artefact in one of its portions - without formal separation. It concerns only the underground structures

(a) Full-width perrons used to stand before urban houses around Kraków's main square, providing access to cellars and ground floor (1/2 level above ground). As in medieval period a level of the ground was quickly rising, perrons got concealed little by little and finally had to be walled in. They are today inaccessible (interred below the actual level of the main square)- (b). They are seen as segmental a naesthesia of the urban houses they belong to.

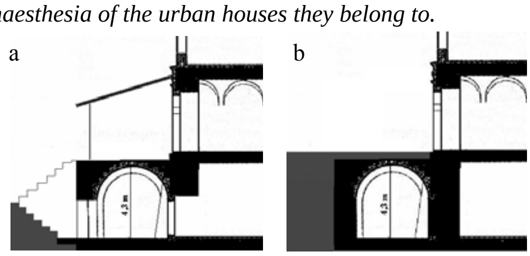


Table 2. Transitions and states occurring within a life cycle.

* It usually took several decades if not centuries to erect a gothic cathedral. When no interruption occurs during the building of an edifice, the whole period is seen as a transition. When on the contrary the work is halted for a significant period, for instance by wars, then a state is created that corresponds to an unfinished edifice. A number of examples exist, such as St Peter's cathedral in Beauvais, of edifices that in the end never were completed.

creation
<transition>
Birth of an artefact (not to mix up with reincarnation, which is a re-birth).

Any act of creation of an artefact, even when long-lasting, provided that a continuous activity can be established on the work site (Sainte-Chapelle, 7 years).

extinction
<transition>
Irreversible destruction of an artefact including sub-structures, with as result, its physical annihilation. Ends not only a life cycle but also the evolution of the artefact.

At the end of the Punic wars Carthago was intentionally destroyed by Romans, who as history tells us salted the area. Carthago was later replaced by a Roman town (later seized by Vandals, and finally destroyed during the Arab conquest) the remains of which one can today visit. The initial town is extinct.

hibernation
<transition>
[state]>
Destruction of the artefact's apparent parts, combined with absence of functional activity inside the remaining inaccessible portion.

Unexcavated edifices of the sites of Pompeii or Herculaneum that can be considered as hibernating until archaeologists uncover them.

internment
<transition>
[state]
Building of a new artefact over a previous one, the latter remaining underneath as an inactive, inaccessible portion called a segment. Internment may be deliberate (ex. preventive archaeological bury) or unintentional.

The Gothic Dominican monastic ensemble built in Saint-Maximin (to protect the relics of Sainte Marie-Madeleine whose tomb was discovered on the site in 1279) was erected on the remains of an antique Roman villa. The site was excavated in the past decades, but archaeologists and local authorities agreed on keeping the Roman remains (that also include an early baptistery) buried.

merge
<transition>
Combining different artefacts or portions of artefacts into a union, that is considered as a completely new artefact.

Collegium Maius in Kraków (where Copernic studied) became the seat of Jagielonian University when king Casimir the Great bought from private owners various properties in order to create a new, compound yet consistent structure.

reincarnation
<transition>
[state]
Re-birth of an artefact in a new embodiment, occurring in particular as a result of excavation and reuse of a hibernating artefact.

The site of Knossos (Crete) was hidden (hibernating) for centuries before 8it was excavated and partly rebuilt at the end of the XIXth century, and then opened to visitors.

split
<transition>
Formal division and separation of an entire artefact into parts, leading to the creation of two (or more) new, independent artefacts.

The former Palace of Diocletian, built by this Roman emperor in the Croatian city of Split, was not demolished but divided into a number of sub-parts, that today, after series of modifications are used as individual artefacts (urban houses in particular).

In some periods houses inside one urban block have q tendency to split (a result of proprieties division)

translocation
<transition>
[state]
Displacement of an artefact or sub-parts of an artefact, caused by human activity.

A part of a temple of Abou Simbel (Ramses II) was dismantled, moved and rebuilt higher backed on to an artificial cliff when lake Nasser was created.

Table 3. Transitions and states starting/ending a life cycle.

3. VISUAL DISPLAYS

3.1 Methodological background and graphic codes

In the field of linguistics, F. de Saussure (see (Klinkenberg, 1996) or (Barthes, 1985)) identified three modes of time existence in human experience – *synchronia* (a time-slot in which an object of our analysis is the same, unchanged), *diachronia* (a period in which the object changes) and *panchronia* (what steps out of time-space continuum and authorise us to state the identity of the object regardless of changes). A thorough understanding of an artefact's evolution requires therefore three-mode analysis – synchronic, diachronic and panchronic.
The methodological approach presented in this paper proposes:

- a diachronic lecture of changes that allows recognition of transitions (sudden or gradual),
- identification of periods of synchronic existence that we call states,
- a pancronic understanding of evolution of an artefact, that allows us to affirm that regardless various changes the artefact rests the same, and state which transformations may alter artefact's identity.

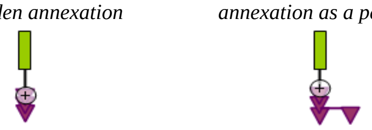
The alternation of transitions and states, projected on the timescale gives us a coherent vision of artefact's evolution.
This framework is used to produce two types of linear diagrammatic representations called *diachrograms* and *variograms* (see Figure 2). The transitions and states are represented by distinctive graphic codes, that permit to read a diagram as a "story about an artefact's evolution".
All the basic graphic codes are represented in the table below. Note, that sometimes the difference between two distinct transitions is not directly expressed by a transition-code (e.g. annexation and merge), but it can be clearly identified by the consequences of a transition. (see Figure 1)

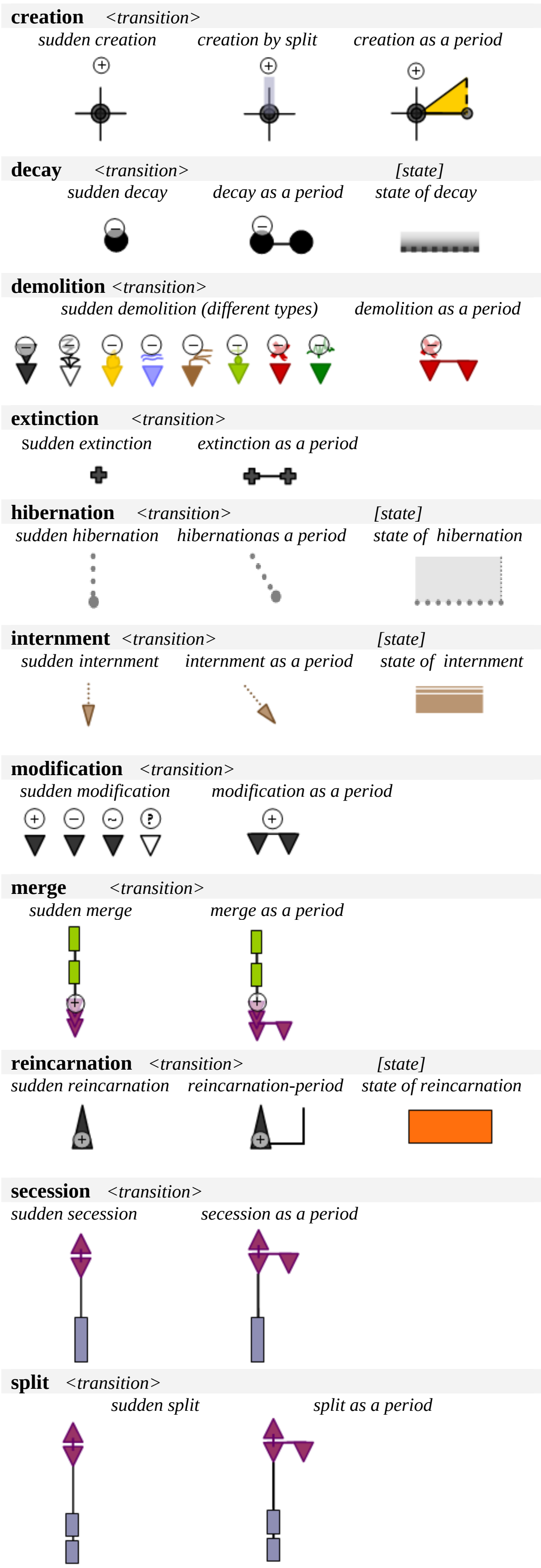
abandon *<transition>* *[state]*

sudden abandon *abandon as a period* *state of abandon*

annexation *<transition>*

sudden annexation *annexation as a period*





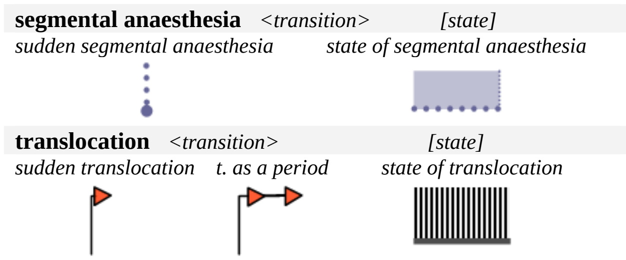


Table 4. Graphical symbols proposed to visualise identified transitions and states.

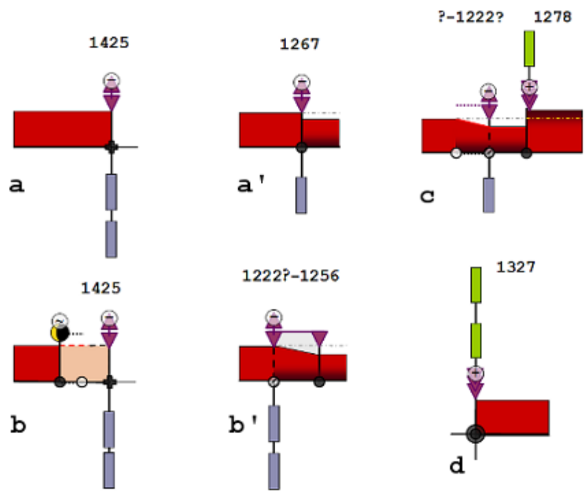


Figure 1: *(a)* sudden split transition of an artefact into two new independent artefacts, marked as two rectangles underneath the time axis; *(b)* same transition, after a period of abandon; *(a')* a sudden secession transition; *(b')* a lasting secession transition; *(c)* a lasting secession transition causes the artefact to diminish, and a following sudden annexation transition has the opposite effect (marked as a rectangle above the artefact's bar); *(d)* as a result of a lasting merge transition associating two artefacts, a new artefact is created;

3.2 Diachrogram

A *diachrogram* represents successive states and transitions for life cycles inside entire evolution of an artefact. They present the evolution of an artefact along a time axis.
The basic components of a diachrogram are a time axis, states and transitions markers, accompanied by the date-certitude indicators (see Fig. 2).

The date-certitude indicators informs us weather the dates of transitions are certain, dubious or vague. They are composed of a circle on the time axis and of a vertical line linking it with a corresponding transition marker. Colour of a circle (grey, dashed or white) and line type correspond to a certitude level.
One marker represents a sudden transition, two interrelated show a lasting transition (and its duration).
It has to be said that a diachrogram represent an expert's view of the artefact: different interpretation of the data may lead experts to propose different chronologies - the diachrogram then acts as a comparative tool.

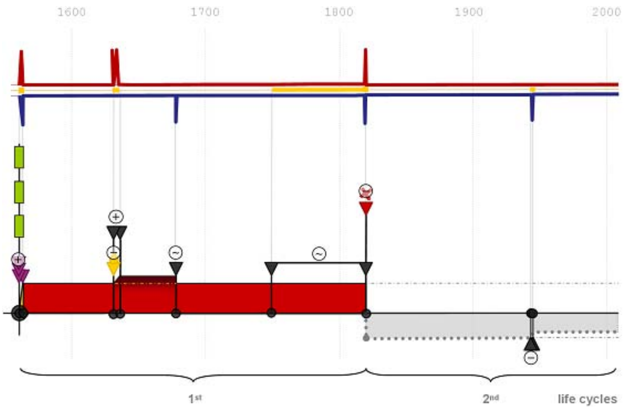


Figure 2: Combined diachrogram and variograms, with *(top)* morphological, structural and functional variograms representing the nature of changes, and with (*bottom*) the full diachrogram representing successive life cycles.

Diachrograms underline visually moments when the edifice tends to "get bigger" (as a result of modification by extension or of annexation for instance). They show the level of certainty or lacking information we have on the dating of events (start and end of events). (see Fig. 3) Colour coding is used to differentiate irregular states (abandon, hibernation, etc.), as shown in Table 4.

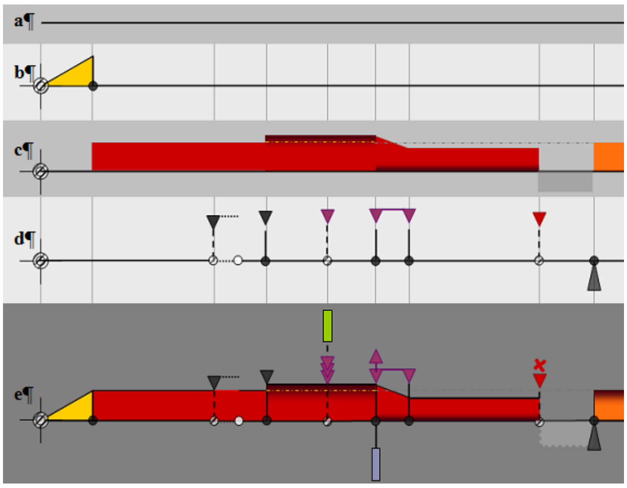


Figure 3: (**a**) the time axis; (**b**) symbols marking start and end of the artefact's evolution (creation) ; (**c**) the artefact's bar, composed of "states" with a dash/dot line acting as a reference to the artefact's initial volume; (**d**) transitions markers and date-certitude indicators (**e**); (**g**) a combination of components.

3.3 Variogram

A *variogram* visualises the nature and relative importance of transformations. It allows to highlight the intensity and duration of changes by combining in a parallel visualisation three aspects:

- morphological (formal changes such as stylistic refurbishing, changes in surface, volume, etc.),
- structural changes (technical changes such as change of roof material, replacement of sub-elements such as floors, etc.),
- functional changes (significant switches in the way the artefact is used).

3.4 Implementation

The implementation of the elements described in this paper, namely a framework of description of architectural changes, and visual disposals aimed at enhancing the readability and comprehensibility of the above mentioned changes, privileges open source and standards for the web. The developments presented in this paper in fact complement. previous works we have carried out on the same field of experimentation - the medieval heart of Kraków (presented for instance in (Blaise, 2007a) or (Blaise, 2005)) - with a focus put in these former actions on relations between 3D/2D graphics and a documentary database. Accordingly, the technical platform used is the same, and combines the following elements:

- a description of artefacts as instances of a hierarchy of classes (in the sense of OOP), with persistence enabled through RDBMS structures,
- outputs (may they be visual outputs – 3D VRML or 2D SVG- or textual outputs –XML) produced by Perl scripts nested in web-enabled pages,
- interfaces produced by Perl scripts either as XHTML or as XML/XSLT datasheets,
- graphics produced by Perl scripts either as VRML files or as SVG files (with included user-controls enabling various interactions within databases).

In this development, we have privileged dynamic SVG (see (Renolen,1997)); but at this stage SVG is used only for data visualisation, the interface itself remaining XML/XSLT (with embedded jscripts). The SVG format has been widely applied both in cartography (see *carto.net repository*) and in infovis. It appears as an efficient solution and allows the level of interaction we expect, with nested jscript when needed.

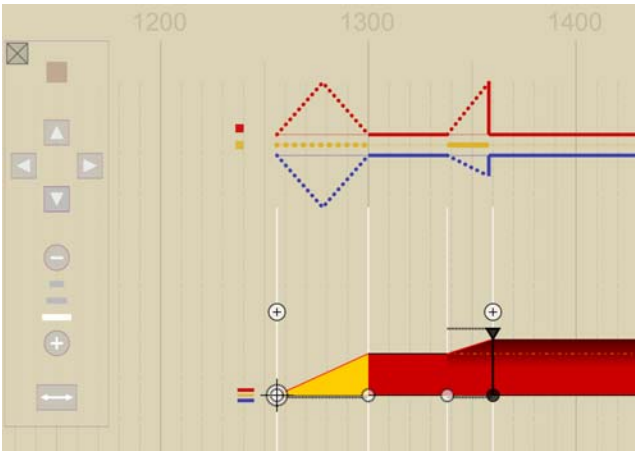


Figure 4: Partial view of a combined visualisation of diachrogram and variogram in the SVG implementation (here real case of the town's "Kramy Bogate", *i.e.* rich stalls). Navigation in and about the scene uses the classic geographic map browsing metaphor with plus and minus signs for zoom factor, and arrows for pan command.

Interaction inside the SVG display allows users not only movements inside a static scene but also control on various elements:

- graphic context (background time grid);
- date markers (white lines and background time grid can be used to check date of event);
- additional information (textual elements given as comment about the event).

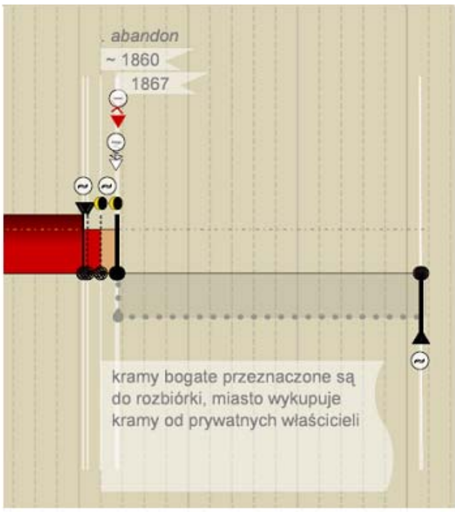


Figure 5: Additional information with specific uncertainty markers for dates (here real case of the town's "Kramy Bogate", *i.e.* rich stalls).

Both the evolution of architectural and urban elements (335 objects, 817 phases studied) and historical sources used during the investigation (761 sources) have been described. The separation of various types of data allows independent growth of each database or data set, and cumulating information brought by specialists from different domains.
Diachrograms and variograms will be produced dynamically for the above mentioned data set, with however a necessary evaluation period needed to test the disposal's efficency as "tool for thinking".

4. EVALUATION

At this stage of our research, evaluation of the disposal as a whole (both the description framework and the graphics) is done by confrontation with experts of the field of experimentation. This is due to the fact that the readability and efficiency of the graphics requires not only a good understanding of historic architecture, but a good knowledge of changes that specifically occurred in the city of Kraków throughout history (in order to point out lacks, underline inconsistencies or misleading visual signs, etc.). Figure 6 shows examples of applications to real cases in the medieval heart of Kraków that are being evaluated (Saint cross church, a middle size, minor religious artefact, and the old town hall, a civil, complex, major artefact).
Once this first evaluation will have been carried out, it may appear necessary to widen the audience in order to better evaluate to which extent the visual disposals themselves are efficient.

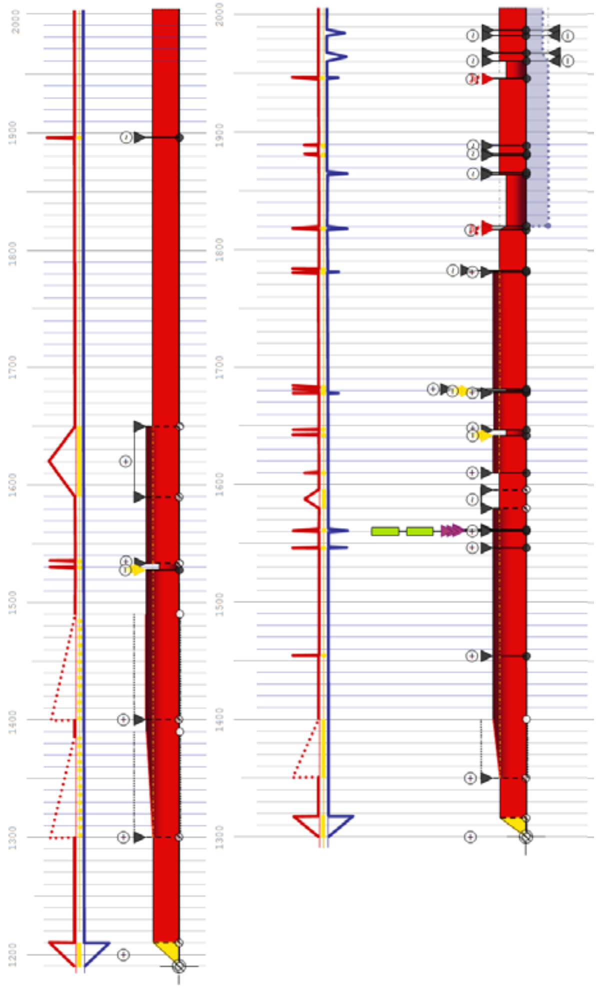


Figure.6: Top: Variograms and diachrogram for Saint Cross church: note absence of functional change (bottom line of the variogram), a typical feature of religious artefacts. Also note strong uncertainties on the dating of the two first transitions; and a short transition due to fire around 1530. Finally, note the stability since mid 17th century, corresponding to the period when the capital of Poland is transferred from Kraków to Warsaw (a drop in the city's wealth). Once cross-examined with buildings around, or with buildings of the same type, this might also indicate a lack of information. Bottom: Variograms and diachrogram for city's former town hall. Note the one-century time slot between the creation of Saint-Cross church and of the town hall. Also note the number of functional changes (bottom line of the variogram): the edifice was used as a town hall, but also during its evolution as a prison, a tavern, a granary, a museum, a theatre, etc.. Note numerous morphological changes, with two fires during the 17th century, and two partial demolitions (19th/20th century). Also, note consequences of the 19th century partial demolition: superstructures diminish; an inaccessible, inactive substructure appears (and remains as such until now). Finally, note the relatively good precision we have on the dating and duration of transitions (except for the first), due to the importance of the

building, and therefore to the amount of documents we have on its evolution.

5. CONCLUSION

Observing that solutions lack when one wants to recount and sum up the evolution of historic artefacts (lacks in terms of method of description as well as of visualisation), we propose and apply a methodological framework dedicated at a diachronic reading of architectural changes. Graphics developed are primarily designed to allow the visual assessment of an artefact's life cycles. In addition, following E.R Tufte's observation (Tufte, 2001) - *comparisons must be enforced within the scope of the eyespan*- they should provide means for visual comparisons (time t_1 to t_n of an artefact's evolution, comparative reading of artefacts). We believe that the synthetic nature of these graphics helps understanding in a cleat-cut manner how changes over time affect architecture, but also underline key aspects of "historical sciences" data: uncertainties, incompleteness, long ranges of time, unevenly distributed physical and temporal stratigraphy, etc..

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