Visual assessment of heritage architecture life cycles

Iwona Dudek, Jean-Yves Blaise

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I. Dudek , J.Y Blaise
(UMR CNRS/MCC 694 MAP, France
idu(jyb)@map.archi.fr

Abstract: When studying heritage artefacts, and trying to represent what we know of them, it is important to portray not only key moments in their evolution, but also processes of transformation. In this contribution, we introduce a methodological framework of description of architectural changes, and investigate diagrammatic representations as means to visualize the above mentioned framework. We introduce two types of diagrams (diachrograms that distribute along a time axis transitions and states, variograms that detail the nature of the changes) that should help better understanding, how changes over time affect architecture. The paper also underlines key aspects of data in "historical sciences": uncertainties, incompleteness, long ranges of time, unevenly distributed physical and temporal stratifications.

Key Words: Architectural heritage, knowledge modelling, Spatio-temporal data.
Categories: H.3.3, H.5.2, J.5, H.1, H.2.5, H.2.8, H.3.1

1 Introduction

Heritage artefacts, may they be individual edifices or whole sites, are rarely left unchanged by time. Natural or man-related events occur throughout the centuries, resulting in transformations that can introduce minor architectural changes (extension, refurbishment, etc.) or cause important modifications, both in terms of physical appearance and in terms of usage. Ultimately, what 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 was at time t_1, t_2, …, t_n. Broadly speaking, such methods rely on "expert-interpretation" (of observations or archival data) and may include cross-examinations of individual cases. 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 visual methods in the analysis of our data set, in order to foster a comparison-enabled, global vision of the artefact's evolution; whereas traditional architectural representation, by privileging shape modelling, tends to enhance states over changes (see[MhMK ,07]).

In the field of linguistics, F. de Saussure (see [Klinkenberg, 96] or [Barthes, 85]) introduced a distinction between a synchronic approach (where the focus is put on a moment in the evolution of the language) and a diachronic approach (where the focus is put on changes extending through time). We have shown that these notions can be a fruitful methodological base in the field of the architectural heritage [Dudek, 07b]. We consider that for edifices too, there can be a synchronic approach, in which artefacts are observed as different moments in their life cycles, and a diachronic approach, where the focus is put on a cause-effect analysis.

In Journal Of Universal Computer Science – Proc. I-Know 2008, 8th International Conference on Knowledge Management, Knowledge Visualization and Knowledge Relationship Discovery Workshop, Graz, Austria, sept 2008

In this paper, we introduce a methodological framework aiming at describing life cycles in heritage architecture, in what can be seen as a diachronic approach. Focus is put on the way artefacts get transformed, with a grid of notions identifying life cycles as a sum of states and transitions. We then introduce the diagrams that act as visual explanations of the artefact's life cycles and provide some examples on major or minor architecture within the medieval part of the town of Kraków (former capital of Poland, experimental set for this research). Concluding remarks acknowledge the remaining steps we need to take and identify the key benefits expected.

2 Objective and context

As shown in [Dudek, 07], cross-examinations of hypothesis about the evolution of heritage artefacts 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 VR, GIS-based site management systems are among the most prominent results such approaches). In contrast, we intend to try and apply, in what we view as a visual assessment of architectural changes, E.R Tufte's *first principle for the analysis and presentation of data :* "*show comparisions, contrasts, differences*" [Tufte, 06].

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 (see [Alkhoven, 93] though). However such approaches can be found outside of the field of the architectural heritage, and in particular in geography (for instance in time-geography [Lenntorp, 03] where the focus is put on time motion. A close example can be found in A. Renolen's graphs [Renolen,97], where changes in land areas are visually assessed through synthetic 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, etc..

We introduce an analysis of states and transitions that we believe better matches the specificity of heritage architecture. Provided that such an analysis is carried out and properly evaluated, visual methods could allow an in-depth analysis of the data, and could offer an unprecedented view on the global evolution of an artefact. In addition, such graphics could possibly *amplify cognition* [Kienreich, 06] by uncovering patterns of evolution within a site or across sites, underlining uncertainties or exceptions ("documentary gaps"), raising questions about the relative evolution of families of artefacts (urban houses in this or that quarter of the city, churches across the city, etc.). Accordingly, our objective is at the intersection of two issues:

- Describing architectural changes (i.e. a knowledge modelling issue),
- Reasoning visually on and about those changes on real cases (i.e. an infovis issue).

3 Method's starting point: a description grid

Our description grid identifies the notion of **artefact** and its possible remaining sub-parts once transformed: a **portion** is a subset of an artefact, it results from its conceptual division into an active part (a **core object**) and an inactive part (a **segment**). We also differentiate its evolution from what we call its life cycles.

- The **evolution of an artefact** is the time slot defined by its creation on one hand (*i.e.* its first appearance), and by its extinction on the other hand (*i.e.* its thorough and irreversible physical removal, including of sub-structures, or its division).
- An **artefact's life cycle** identifies a time slot corresponding to a consistent physical continuum, time slot during which transformations are partial (*i.e.*, the artefact is neither moved nor entirely subdivided into new independent structures).

Given the above definitions, an artefact's evolution may therefore contain several cycles of life. Each life cycle can consist of a number of **states** and **transitions**. **States** are 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 transitions, 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.

The proposed description grid identifies seven transitions and states occurring within a life cycle (**abandon, decay, annexation, demolition, modification, secession and segmental anaesthesia**); as well as 8 transitions and states starting/ending a life cycle (**creation, extinction, hibernation, internment, merge, reincarnation, split and translocation**). We hope tags used to denote these transitions ans states are illustrative enough to let the reader grab their semantics and will focus on their practical use. Basing on the above framework, two linear diagrammatic representations are proposed, called diachrograms and variograms, combined with one another and with a time scale that matches the artefact's evolution. The next sub-section introduces a brief description of their content and role in reasoning about the artefact.

4 Visual methods of analysis

Diachrograms present the evolution of an artefact along a time axis. They are composed of a set of visual indicators representing successive transitions and states combined into life cycles. Their basic components are represented in Fig 1. As will be shown through the examples presented below, visual analysis of a diachrogram combines a global view (density and time distribution of changes) with a local view (individual features of changes, events and interaction) on one artefact (Figures 1 to 4). It also allows for a comparative view over the collection of artefacts we have studied, with uncertain / lacking data stressed.

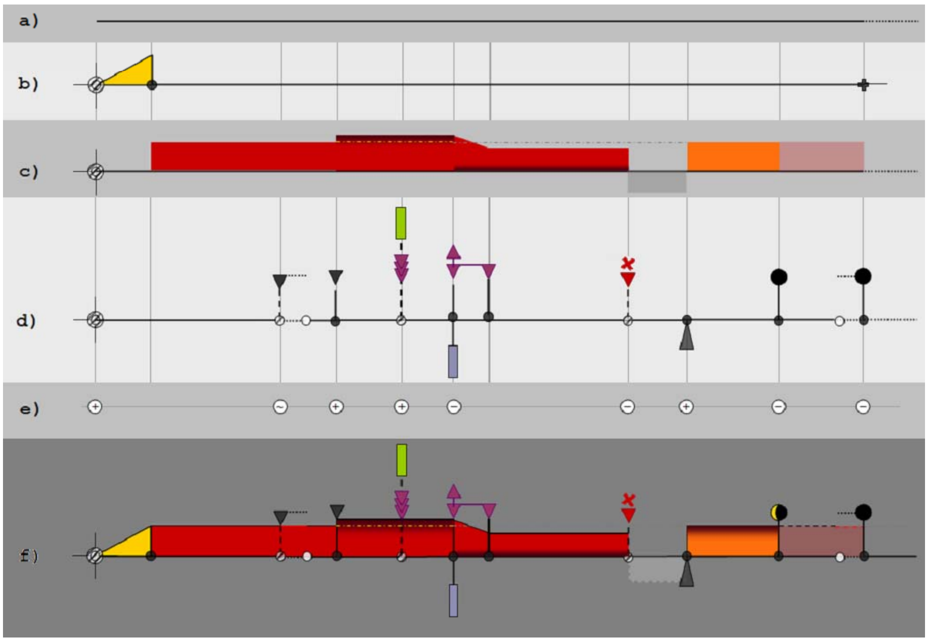

Figure. 1. A diachrogram composition; (a) the time axis; (b) symbols marking start and end of the artefact's evolution; (c) the artefact's state-bar, composed of diversely filled "rectangles" (different colour- different state) with a dash/dot line acting as a reference to the artefact's initial volume; (d) transition-markers, composed of a circle on the time axis and of a vertical line topped by symbols representing transitions. One marker represents a sudden transition, two interrelated show a lasting transition (and its duration). Vertical (green) rectangle(s) above a transition-marker indicate an annexed portion(s) or artefacts, vertical (blue) rectangle(s) below it indicate portions withdrawn form the artefact (e) additional transition qualifiers, stating how the artefact's volume is changed; (f) a combination of the basic components.

It has to be said that a diachrogram represent an expert's view of the artefact: different analyses of the information gathered on an artefact may lead experts to propose different chronologies - the diachrogram then acts as a comparative tool. The graphic system for the 15 states and transitions identified in section 3 combines 86 transitions markers, 21 state markers, 15 event markers. We do not present each and every combination but show typical examples of use and full-size real-cases.

Figure. 2. Transition markers, example; the colour of triangles (and sometimes their number) indicates the transition type and a cause of transformation.

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). Both transitions and states are represented, with life cycles notified by symmetry along the time axis. Colour coding is used to differentiate irregular states (hibernation, reincarnation, abandon, etc.), as shown on Fig 3.

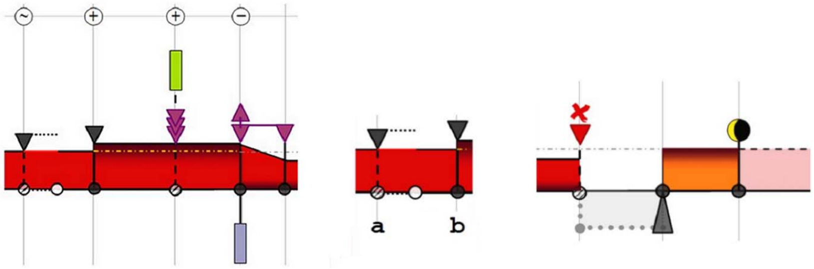

Figure. 3. Left - a visual indication of trend ("gets bigger", "gets smaller"). Middle - the intensity of circle's filling indicates the level of certainty of the dating (thee levels); Here a lasting transition with an uncertain start date and an unknown end date (a), and a sudden, well documented transition (b). Right - alternative colouring used to identify hibernation, reincarnation and abandon states.

In the case of demolition or extinction, an additional pictogram is positioned above the transition visual marker in order to deliver information on the causes of these transitions (of course, when we have enough data to state this: if we have no such data a white filling indicates our ignorance) (*cf.* Fig 3). A specific triangular shape is positioned below the time axis to mark the reincarnation transition.

When a diachrogram distributes along the time axis transitions and events represented as "typed global events", a variogram further details the nature of the changes on the artefact. It is used in combination with a diachrogram.

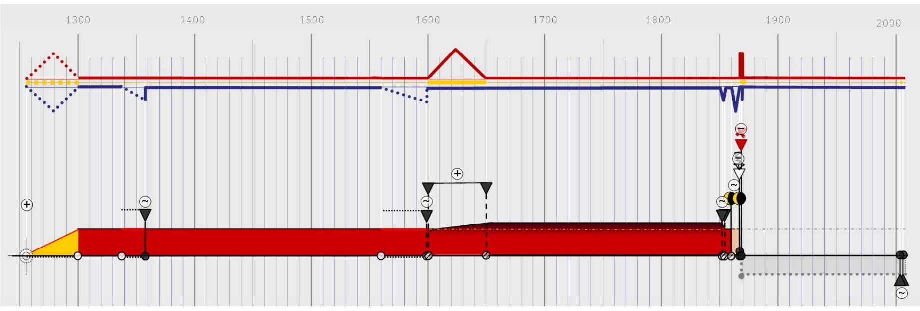

Figure. 4. Variogram and diachrogram for Halles aux Draps; note: a) uncertain period of construction (white dating-circles), b) the first and the second exclusively functional modifications (bottom line of the variogram) the duration of which is not established (at least one date of each period is unknown), c) the third morphological and structural transition (construction of a new roof), the duration of the construction period is too long not to be questionable, d) the last group of functional transformations preceding roof collapse and object's demolition (repurchase of an object by a principal owner) and e) underground structures (primal ground-floor) are not demolished, they are hibernating under the ground level, they have been studied (see the last non-invasive intervention of archaeologists) and it is not excluded that it will be brought to live through the reincarnation transition.

A variogram highlights the intensity and duration of changes by combining in a parallel visualisation three aspects:

- morphological changes (formal changes such as stylistic refurbishing, decoration, or 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, or change of owners).

Variograms help visual underlining of coinciding changes and stress possible links between these three aspects.

5 Implementation and evaluation

This development complements previous works we have carried out on the same field of experimentation - the medieval heart of Kraków (presented for instance in [Dudek, 07] or [Dudek, 05]). Accordingly, the technical platform used is the same:

- 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 (in our first experiments) or as XML/XSLT datasheets,
- graphics produced by Perl scripts either as VRML files or as SVG files.

Both the evolution of architectural and urban elements (341 objects, 885 phases studied) and historical sources used during the investigation (791 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. In this development, we have privileged dynamic SVG (see [Rathert, 05]); but at this stage only for data visualisation, the interface itself remaining XML/XSLT.

At this stage, 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 assessment of the graphics requires not only a good understanding of historic architecture, but also a deep knowledge of changes that specifically occurred in the city of Kraków (in order to point out lacks, underline inconsistencies or misleading visual signs, etc.). Accordingly we interrogated only four experts, which of course makes our evaluation an indicative one (naturally, after modifications resulting from this evaluation the disposal will be evaluated by widen the audience).

We conducted a two-stage evaluation: direct responses (rating from 1 to 5) collected on eight questions, corresponding to four criteria; and an impact assessment phase during which we identified one by one the consequences yielded by the introduction of the disposal on real cases. Tables 1 and 2 present a brief overview of the results. In short, they show the disposal fosters understanding of changes, usefully uncovers debates, but also has remaining limitations, in particular on time granularity and on showing alternative data interpretation.

readability - (of chronology, states and transitions)	4,85
usefulness in the investigation - (for reasoning, for communication)	5
validity - (ability of the expert to validate elements of the life cycle)	4,83
relevance to the domain - (uncertainty or fuzziness handling, realistic description of artefact changes)	4,25

Table 1. Direct responses collected from experts (left - criteria, right - average rating)

Presented diagrams :
Foster and uncover new debates on artefact changes among experts, and strongly encourages workgroup discussion.
Are an efficient disposal for information exchange - uncovering of inappropriate dating, reviling of differences in understanding of an artefact's evolution (diachrogram was found more efficient than a language (spoken or written).
Are effective in comparisons, they allow establishing parallels and underlining inconsistencies inside a collection of artefacts (even for typologically distinct objects).
Underline the need of modifications in spatial granularity.
Do not permit variations in temporal granularity.
They do not take into a consideration the relative importance (in size and significance) of the artefacts.
Do not show clearly the moments of uncertain artefact's evolution, when alternative solutions can be proposed.
As next step, new possible uses of diachrograms were identified (e.g. sorting out events by type in order to underline for a frequency of fires according to artefact's location, structure, etc.).

Table 2. Impact assessment, with key benefits and remaining limitations.

6 Conclusions

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, 01]: *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). The proposed graphics have proved to meet two other principles for the analysis and presentation of data quoted by [Tufte, 06]: *show causality, mechanism, explanation, systematic structure* and *integrate evidence*. Yet their very nature (structured, commented, time-related diagrams) introduces a strong constraint: diachrograms and variograms are essentially one-dimensional narrative disposals.

Accordingly, a truly multivariate analysis of architectural changes has to be accompanied by complementary spatially and dimensionally determined disposals, a direction we have already investigated. Furthermore, going back to Tufte's principles once again, our constant concern in the past years (see for instance [Dudek, 05b], [Dudek, 07]) has been to thoroughly describe the evidence (including by uncertainty "measurement"). Consequently, the development we present complements (and results from) a thorough investigation of artefacts. Diachrograms/variograms should not be seen as an end, but "yet another mean to perform reasoning tasks" about a data set, and are to be integrated to the global information model described in [Dudek, 05].

Given these precautions, the results we report show that visual thinking can fruitfully apply to the assessment of architectural changes. Provided a relevant knowledge modelling effort is carried out, we believe that the synthetic nature of the graphics proposed 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 stratifications, etc..

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