UNDERSTANDING CHANGES IN HERITAGE ARCHITECTURE
Can We Provide Tools & Methods for Visual Reasoning?

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Abstract: When studying heritage architecture, and trying to represent and understand the development of artefacts, one should not only examine key moments in their evolution, but describe the whole process of their transformation - thereby correlating *contextual causes* and *architectural consequences*. In this contribution, we introduce a methodological framework of description of architectural changes, the corresponding visual tools, and finally present elements of evaluation. The results we report show the description framework favours information discovery: cross-examination of cases, analysis of causal relations, patterns of change, etc.

1 INTRODUCTION

Historic artefacts are today widely regarded as landmarks in our cities: physical landmarks as well as symbolic ones. They act as tangible traces of a broad, conceptual notion: time passing by, and the metamorphosis of societies and cultures. And so when wanting to actually analyse and understand those artefacts, it is important to figure out that we deal with history as well as with architecture. Artefacts tell us how we became who we are, with successive, wanted or unwanted, transformations and influences. A scientist's view over historic artefacts thereby necessarily integrates heterogeneous information sets with a strong predominance of issues typically found in historical sciences - uncertainties, incompleteness, long ranges of time, unevenly distributed physical and temporal stratification.

So the key point here is how can we better link the objects we study, architectural artefacts, with the information needed to understand their changes. Let's take a quick example: in 1367 a major fire bursts out in the city of Krakow (Poland), spreads from roof to roof and causes huge degradations. As a consequence, a new law is adopted that states a high wall should from then on separate each dwelling from the neighbouring edifices so as to avoid "fast fire propagation through roofs" (Fig. 1a).

As a consequence, the outlook of urban blocks dramatically changes. Fire walls are built between edifices, roof slopes are inverted – from outbound to inbound - with a central gutter for rainwater (Fig 1b) hidden by a high decorative wall along the street called attic (Fig 1c).

With time passing by, the wiklerz 1367 rule is abandoned, but the image of attics remains as a cultural landmark. New edifices continue to be designed with high attics although no constructive or legal reason subsists. So how can we today explain the presence of attics in Krakow's cityscape, if not by mentioning the notion of "fire", if not by linking architectural consequences with their historical causes?
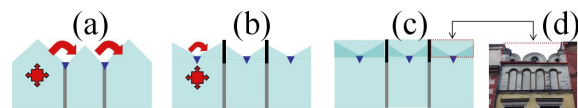

Figure 1: (a) a fire occurring in the first artefact spreads to others through roofs. (b) new law promotes fire walls in between dwellings (black) to prevent fires - roofs are reversed with gutters (blue dot) in the middle of the façade. (c) in order to hide the new fire roofs decorative attics are built which remain until now (d).

The idea that artefacts are *tangible education* is not new. XIXth century pioneer of architectural conservation Viollet Le Duc wrote a famous book in which he uses an imaginary city to recount the evolution of rules and customs of urban societies since the end of the Roman Empire.

He thereby underlines how the successive transformations of artefacts are inherent consequences of events, trends, facts – *i.e.* of a

context. The context does not necessarily explain the architectural solution itself, (like in any art-related practice) but it helps understanding what causes led to wanting a new architectural solution.

Our contribution can be seen as an application of Viollet Le Duc's vision: we propose a methodological framework aimed at identifying and describing causes the consequences of which can be read on the artefact itself. More precisely, the lifetime of an artefact is considered as a continuous chain along which two types of links alternate: transitions (changes) and states (periods of stability). In a previous contribution (Dudek and Blaise, 2008a), we introduced this research's scientific background, our early ideas on the description of artefact changes. In this paper, we will first take a broader but brief look on the scientific background, and present key aspects of the description grid. We will then detail how we completed the methodological framework, its visual tools, and finally present and discuss the evaluation procedure.

2 BACKGROUND AND OBJECTIVE

Providing models to handle the dynamics of change has been, and remains, a hot research topic in geography or geospatial sciences. Applications range for instance from the analysis of human movements (Zhao, 2008) to the visualisation of physical phenomena (Knopf, 2002). A set of examples well-known to SVG developers is the carto.net repository - with for example the classic Choroplethe map "social patterns of Vienna" by A.Neumann (Neumann 2005). However these applications focus on the modelling of dynamics that have little to do with the very nature of data sets handled in historic sciences (uncertainties, incompleteness, varying credibility of sources, etc.). Furthermore, even when dealing with urban changes - see for instance (Hagen-Zanker, 2008) - most approaches use a systematic spatial clustering that cannot be transferred (without losses in semantics) to ill-defined architectural spaces. The issue we were facing when starting this research resembles what (Hagen-Zanker) identifies as the drawback of "descriptive models [...] based on static situation": a weak understanding of processes and of causal relations. As mentioned in (Dudek and Blaise, 2008a), 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. A. Renolen's graphs (Renolen, 1997), where changes in

land areas are visually assessed through synthetic diagrams, can however be quoted.

Renolen describes and represents territorial changes: he isolates states and defines events causing changes – notions that we do implement. However, his field of application is land areas as seen by a geographer, and the graphs proposed are far from being applicable to architectural changes. Nevertheless his point is a vital one : on one hand he develops a theoretical model of a dynamic spatial phenomenon, on the other hand he develops a visual "language" using metaphors and/or formalisms used in visualising temporal data (although in a rather straightforward manner, notably without assessing duration and intensities, as defined in (Sabol and Scharl, 2008) or (Blaise and Dudek, 2008b). Accordingly, our objective ultimately meets two complementary issues:

- describing architectural transformations (i.e. a knowledge modelling issue),
- reasoning visually about those changes on real cases (i.e. an infovis issue).

Given a robust methodological framework, and efficient diagrammatic representations as means to visualise this framework, we expect graphics to help *amplify cognition* (Kienreich, 2006) over artefact changes by uncovering patterns of evolution within a site or across sites, by underlining uncertainties or exceptions ("documentary gaps"), by 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.). In other words, 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 comparisons, contrasts, differences*" (Tufte, 2006).

3 THE DESCRIPTION GRID

We introduced in (Dudek and Blaise, 2008a) a theoretical description identifying an artefact's life cycles as sums of states and transitions. Broadly speaking, the description grid's objective is to give professionals the means to describe, date (with uncertainty assessment), and order meaningful events, facts, and elements of context (meaningful - *i.e.* needed to understand the artefact's changes). This selection of events/facts/elements of context is our *a priori modelling bias* (Francis, 1999), based here on an intersubjective analyses of sources.

We sum up principles, findings and recent developments of this first step in section 3, before detailing in sections 4, 6, and 7 the framework's
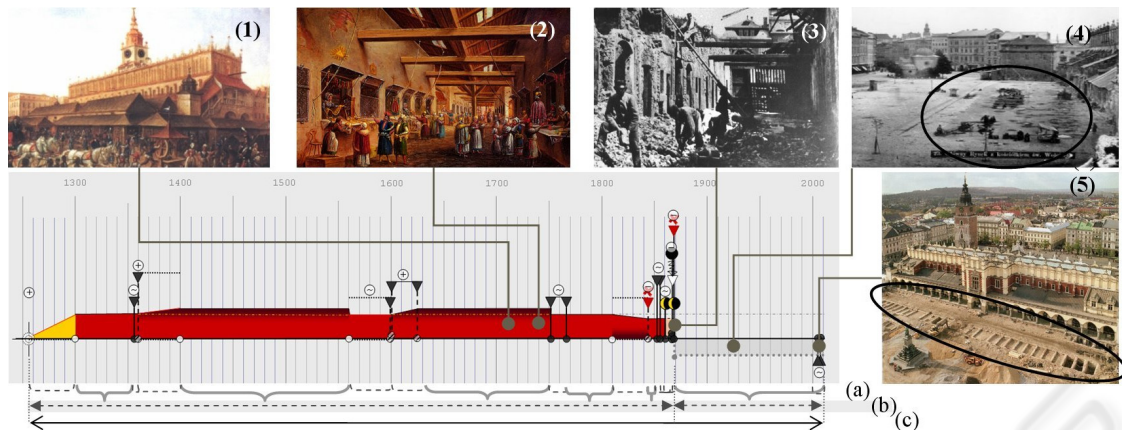
Figure 2: Description grid illustrated on Kramy Bogate (rich stalls), an edifice demolished in the second half of the XIXth century but with important remains (a whole storey in fact) under the level of the actual market square. Top, (1) to (5), archival material documenting states and the demolition transition (3). Bottom, (a) states and transitions - (b) life cycles - and (c) evolution.

completion, evaluation and analysis.

The description grid poses three principles:

- Transitions ≠ states - Transitions identify changes of the artefact - they act as causes. States correspond to time slots during which no major transformation occurs.
- Evolution = ∑ (life cycles) – An artefact's evolution encloses all transitions and states occurring during its lifetime. But an artefact may be transformed to the extent that it only remains as an underground, buried structure. Thus transitions and states can be grouped into periods of visible or of concealed existence that we call life cycles. (Accordingly an artefact's evolution may contain several life cycles - think of Pompeii, once a Roman city, then buried under ashes, and now living a third life cycle as tourist sites).
- Artefact = ∑ (portions) – Divisibility of an artefact when it is transformed (an artefact may be subdivided into portions that live autonomously).

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 or ending a life cycle (creation, extinction, hibernation, internment, merge, reincarnation, split and translocation). Tags used to denote these transitions and states have been chosen as illustrative enough to let the reader grab their semantics. However, tags use ethnic languages, and thereby remain somehow ambiguous, with possible misinterpretations of notions like *hibernation*. Accordingly, each transition / state is denoted by a tag, for communication purposes, and also defined by non-

ambiguous properties that help the analysts choose the one transition or state that best fits his needs.

We do not detail this aspect since this paper does not focus on modelling problems but readers may find an abstract of these definitions in (Dudek and Blaise, 2008a). Let's still give an example: we define internment as the "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". In that case an artefact A is buried underneath a new, independent artefact called B. Internment requires that A becomes an inactive and inaccessible portion, with no physical or functional continuity with B.

3.1 Reasoning Visually about Changes

Basing on the above framework, two linear diagrammatic representations are proposed, called diachrograms and variograms. They can be combined with one another and displayed along with a time scale that matches the artefact's evolution.

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. They rely on the classic concept of timeline (Blaise and Dudek, 2008b), with markers that position transitions, states, and causality assessments along the time scale. 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.

Variograms further detail the nature of the artefact's transformation by combining in a parallel
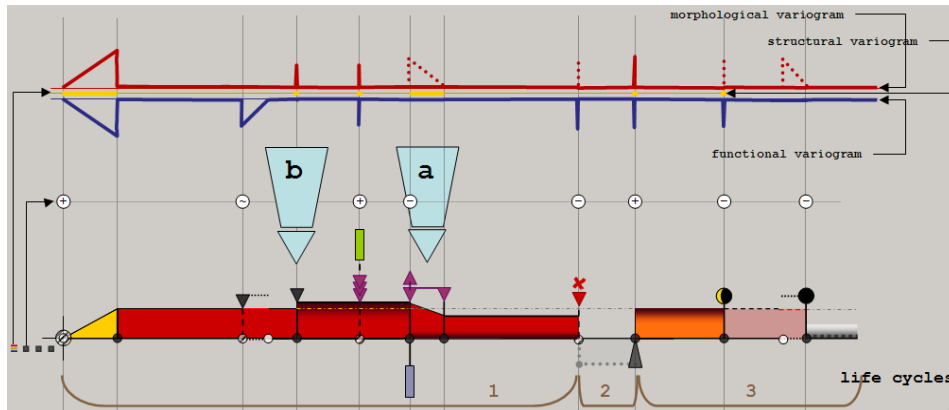
Figure 3: Top: variogram – movements and magnitude indicate periods of morphological, structural or functional changes and their intensity. Bottom, diachrogram sums up visually life cycles, transitions and states. Beginnning and end of transformations are marked by a circle (filling identifies certainty of the underlying information). Transformation types are represented by symbols situated over the dating circles along a vertical line. (a) lasting transition – two dates needed to spot the period of changes, (b) sudden transition – one date only.

visualisation three categories of changes:

- morphological transformation (formal changes such as stylistic refurbishing, decoration, or changes in surface, volume),
- structural changes (technical changes such as change of roof material, replacement of sub-elements such as floors),
- functional changes (significant switches in use or owners).

Variograms help underlining visually coinciding changes, and stress possible links between these three aspects. Durations (with their uncertainties) are visualised, as well as intensity (Fig. 3).

4 VISUALISING CHANGES OF INDIVIDUAL FEATURES

The evaluation of the variogram + diachrogram disposal showed its efficiency in underlining and ordering changes: the disposal gave a good global vision on successive transition and states (see Dudek and Blaise, 2008a). However it gave *only* a global view: it showed for instance that "a fire occurs at period *p*" but did not detail its actual consequences on the various features of the artefact. We therefore completed the description grid in order to allow the visualisation of consequences events have on the artefact's individual features (change in size, in style, in construction material, in owner).

For each category of changes a specific list of features is proposed, with varying variable types. For instance, the number of storeys can be given by an Integer, whereas the stylistic changes require lexical scales. Visualisation of each feature's

chronology is combined with variograms and diachrograms in a linear, timeline-like disposal. The visual solution, inspired by E.R Tufte "data-ink ratio principle" (Tufte, 2006), combines a limited number of elements: lines, dots, colours (Fig. 4,5,6,7).
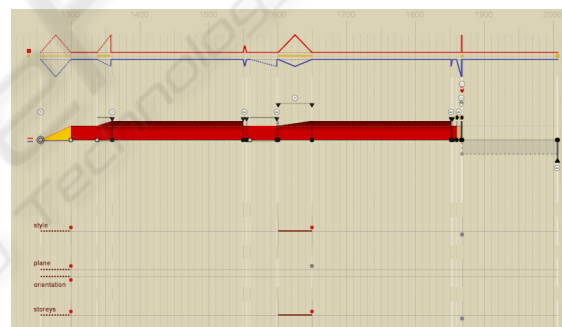

Figure 4: features chronology (bottom, partial view) combined with diachrograms and variograms in the SVG implementation of the framework.

Features we handle are represented by different variable types. A consistent, easy to read, visualisation features variations was therefore a challenge (comparing visually increase in number of storeys - an integer, and style - a closed lexical scale,and with owners - an open lexical scale, may lead to noisy effects such as over-emphasising a feature because of the lexical scale's size).

As an answer, we chose to produce for each feature two different graphics, an *activity indicator* that only says "this particular feature changes at period *p*" and a *feature readout* that details the change. On dynamic loading of the graphics only the former is displayed. Selecting it commands the opening of the second (see Fig. 5).
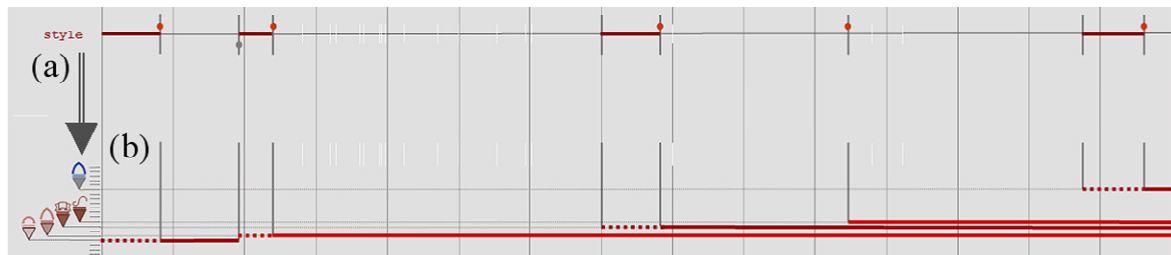
Figure 5: (a) - *activity indicator* for feature "style"– when selected by the user opens (b) - *feature readout* (here stylistic affiliations represented by icons – Romanesque, Gothic, Renaissance, Baroque and neoGothic elements successively appear during the evolution of the artefact). Thick lines on the *activity indicator* identify periods when the feature appears. The continuous lines in the *feature readout* indicate the feature persists in time (note here that the bottom line – Romanesque stylistic affiliation – ends with the appearance of gothic elements, a visual indication that the initial structure is not complemented but replaced).

The **activity indicator** is displayed first. Its role is to position changes (with their intensity) along the timeline, in the most "economic" way possible. Since variation assessment is represented by an integer, its visual marker can then be the same for each feature. Colours indicate the category of changes to which the properties correspond (morphological, structural or functional), dots over the timeline indicate additions and dots under the timeline indicate losses.
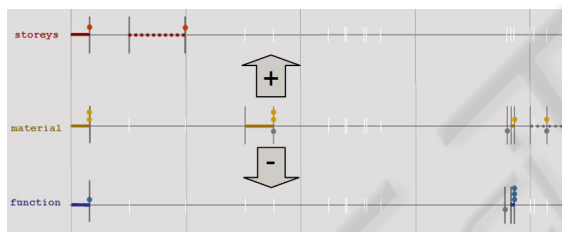

Figure 6: *activity indicator* – examples for the three categories of changes. Plus and minus signs indicate here "'two materials added to the artefacts and one withdrawn". As can be noticed on this example, changes in material reported here had no correlated consequences on number of storeys or function.

Once an activity is reported by the above *activity indicator*, more can be learnt on its nature from the **feature readout**. It details the architectural consequences of changes. Feature readouts have visual markers that match the specificity of the underlying variables and - although we tried to keep a visual consistency by privileging simple lines - their visual "weight" varies. Legend of the readouts can use either icons or tags, depending on whether the lexical scale is closed or not.

The full visualisation of the completed description grid in definitive combines three tools for reasoning - diachrograms and variograms that allow a global view on changes, and features visualisation disposals that foster comparisons across features. The whole disposal is designed to combine vertical readings - "what precisely happens at period p" – and horizontal readings " how does a feature change with time" (Fig. 8). In that sense, the disposal matches Bertin's view of graphics as "visual answer to a question" (Bertin , 1998).
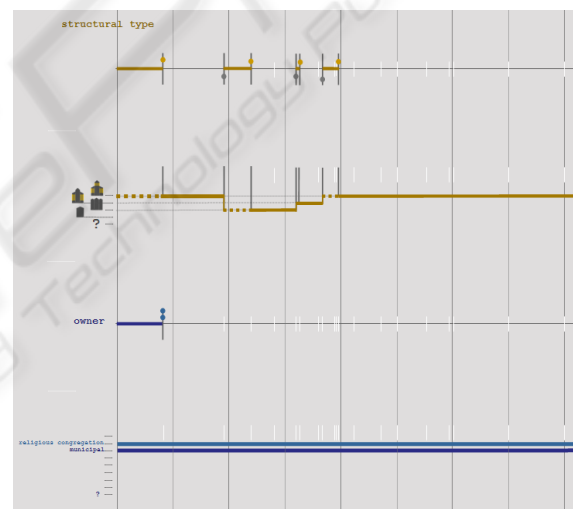

Figure 7: Two feature readouts (example of a church): the top one uses a list of icons corresponding to canonical structural types for churches (hall, basilical, pseudo-basilical), the bottom one a list of tags for the owners. Note that if the artefact's structural type does change with time; its owner remains here the same – a typical pattern for this family of artefacts.

5 IMPLEMENTATION

This development complements previous works on the same test field - the medieval heart of Kraków - presented for instance in (Blaise and Dudek, 2005) or (Blaise and Dudek, 2007). Accordingly, the technical platform is here the same:

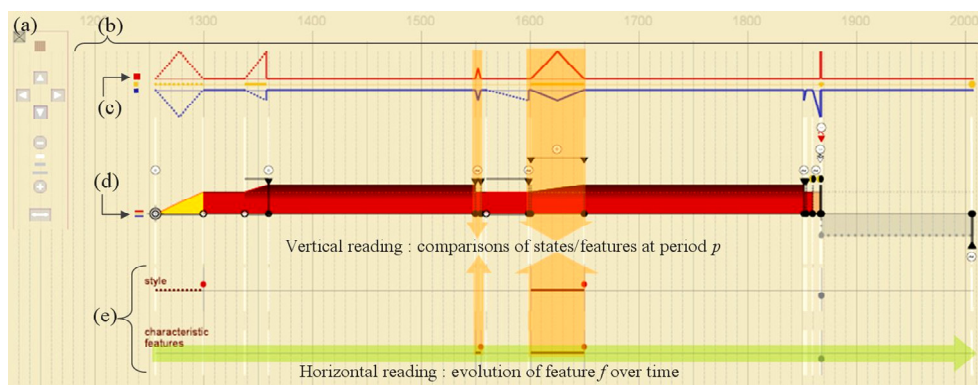- a description of artefacts as instances of a hierar-

Figure 8: (a) Jscript nested interactive commands (zoom, pan, etc.), (b) time grid, (c) features visualisation open/close buttons, (d) variogram open/close button (e) feature activity indicators (partial view) - SVG implementation of the framework.

chy 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,
- interfaces produced by Perl scripts either as XHTML (in our first experiments) or as XML/XSLT datasheets,

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. Graphics are dynamic SVG outputs (see Rathert, 2005). The whole system is flexible to incremental data update.

6 EVALUATION

In a preliminary evaluation (Dudek and Blaise, 2008a), experts of architectural conservation working on our field of experimentation considered that the notions we introduce (*i.e.* the knowledge modelling level) are relevant. Still their opinion could be seen as biased on two aspects: they know very well the artefacts we have described, and moreover they know us … It was therefore important, before trying to conclude on the possible benefits of the methodological framework, to carry out a more open evaluation. Is the whole disposal workable for non-experts? Do non-experts learn anything about an artefact when handling the disposal? Do they learn more about how artefacts change with time by the cross-examination of cases? Unlike in (Dudek and Blaise, 2008a) where the focus was put on knowledge modelling issues, we here focused on understanding to which extent the tools and method do help reasoning visually about artefact changes. Accordingly, both the graphics and

the underlying semantics are concerned, with a series of tests shortly described hereafter.

6.1 The Evaluation Procedure

The evaluation was carried out with two groups: four students in mechanical engineering (no background at all in architecture or architectural conservation), and five students in digital architecture (PhDs dealing with survey issues mainly - background in architecture, art or civil engineering but not in architectural conservation, with two of them having a background as archaeologists). The numbers of testers is extremely limited, and the evaluation therefore does not claim more than giving us hints on where to go next. The groups also differ in cultural background (five nations, from China to Morocco). We gave them a 45' introduction to the methodological framework. We then proposed three successive series of tests:

Memorisation and Reproducibility Tests. We here tried to evaluate with 14 questions "to which extent the visual solution is readable" (weight of graphics, efficiency of the colourisation, readability of the transition/state successions, etc.). Diachrograms, variograms and feature visualisation disposals were projected on a screen for 30 seconds, and then replaced by a specific question on the graphics' content ("how many life cycles did you see", "any differences between blue and red line of the variogram", "redraw the profile of a diachrogram"). Time was not counted.

Clarification Tests. The disposal uses visual formalisms that may lead to possible ambiguities: icons and multilayer feature readouts in particular. In a short questionnaire (4 questions) groups were asked to match either icons or sections of feature readouts with pictures or schemas (see Fig. 9).
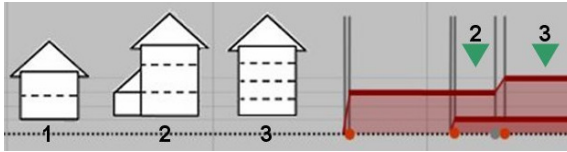
Figure 9: Groups were asked to say which of the three schemas on the left (1,2,3) does not correspond to section of the storeys readout (marked here by green arrows).

Exactness, Efficiency and Discovery Tests. We here tried to evaluate (20 questions) "to which extent the disposal is workable". This time each member of the groups was given a complete real case example presented as printed material. Questions were projected on the screen that required testers to actually read specific information on the graphics with time counted.

The **exactness** test questions required only a good understanding of the disposal, but no interpretation capacities (questions like "longest transition", "number of transition types" are straightforward once the mechanics of horizontal/vertical reading is understood). The **efficiency** tests required limited interpretation capacities - properties needed to be cross-examined, like "find consequences of event E" or "compare number of changes of features plan and style". Finally, the **discovery** tests questions clearly stepped out the reading of values and required analytical reasoning over features and cases ("what relation can you find between number of storeys and number of functions?" or "point out and explain a non-regular functional behaviour among cases"). For this last test the groups were allowed to compare cases.

6.2 Analysis of the Outputs

Memorisation and Reproducibility Tests. We analysed the answers with regards to three criteria – layering and separation (typically necessary to distinguish transitions and states); reading of values (such as dates or transition types), identification of profile (global view on the artefact's evolution). One has to keep in mind that testers had to answer questions using their visual memory. Results in Table 1 show the percentage of testers who could give answers.

Table 1: Percentage of testers who gave answers.

criterion	1st group	2nd group
layering and separation	85,8 %	80,6%
reading of values	73,25 %	71,25%
Identification / reproduction of profile	69,3%	81,3%

Considering the narrow number of testers, significant differences between the two groups are only visible on the last criterion. The first group (mechanical engineers) shows weaker capacity to identify and reproduce profiles of diachrograms and variograms, and was not sensitive to differences in the weight of graphics. This may be due to differences in education: the second group practices drawing on an every day basis. Both groups found the test equally difficult, and declared a same level of familiarity with memorisation tests. On the overall, results show the visual solution is rather easy to understand and memorise. The readability of sequences (cause/consequences) is particularly eased ("layering and separation" criterion) with over 80 % of testers in both groups that become able to date, order and reproduce from memory an artefact's transformations (new to them, naturally) after having seen our visualisations on a screen for 30 seconds.

Clarification Tests. Surprisingly (when considering they declared they know very little about the architectural heritage), the group of mechanical engineers has higher overall results (80% vs 61%) notably on matching styles and their icons (81 % vs 45%), although the other group better identifies styles on images (80% vs 62 %). It is possible that this is because mechanical engineers had little aprioristic knowledge on architectural heritage, and therefore did not compare icons with previous images they had.

It is important to also consider here the cultural diversity of the group, which probably weakens the tests. Inside each group, results of individuals vary strongly. In conclusion, these clarification tests lead to a rather consensual observation: when the semantics behind graphics is strongly domain-dependant, one can hardly escape from providing a good legend.

Exactness, Efficiency and Discovery Tests. With only three wrong answers out of 90, exactness tests show that even with a rather short introduction to the disposal, both groups could rapidly grab its logics. However testers were asked to show their answers to monitors before validating them, and so three wrong answers means here "testers who never could find the correct answer".

Monitors counted retries, which average at 0.52 per person and question. The average value however gives an unfair view: if taking the six best, average is 0.18 per person and question. This shows some testers had clearly more difficulties than others, a problem that may be connected with fluency in language, but that in all case would require more investigation.
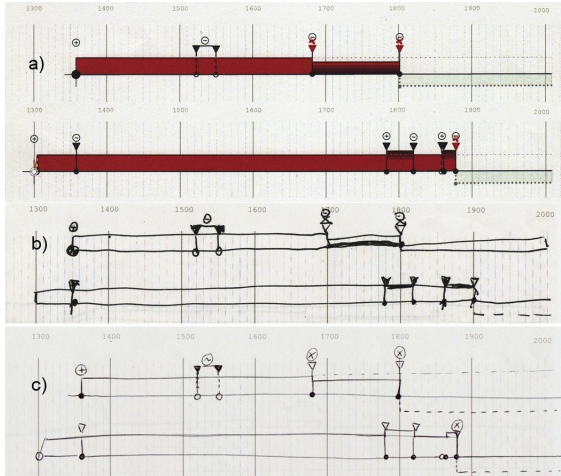
Figure 10: (a) Two diachrograms projected for 30 seconds. (b), (c) these diachrograms redrawn from memory by testers (b least performing tester, c best performing one) – the readability of sequences and their memorisation appears quite convincing. Time slots are respected, the nature and duration of changes as well, and in (c) the state of hibernation of these two examples duly noticed.

In the efficiency tests we added a time constraint. Results are this time of two wrong answers out of 90, and the average retry rate falls to 0.26 – 0.11 for the six best. Under time constraint, testers perform better, which seems to indicate that although complex at start, the disposal has a fast learning curve.

The two groups however performed differently as far as time is concerned: whereas for the first group answers required for 85 % between 1 and 2 minutes, only 18% of answers required more than 30 seconds in the second group. At this stage it is reasonable to consider this as a bias in the monitoring of the tests.

Finally, in the discovery test we allowed no retry. Wrong answers (including "no answers") remain at a reasonable 9 % rate. Furthermore, in 73 % of cases testers could uncover by themselves a causal relation or a specific pattern (topological relation of objects by observing consequences of fires, horizontal functional variogram for churches, etc..)
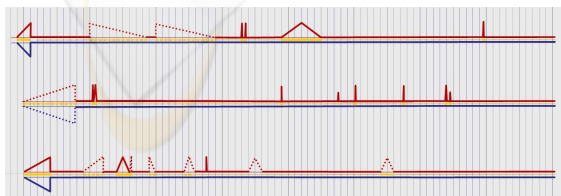

Figure 11: Observing resemblance of the three variograms above, testers could uncover by themselves the functional variogram pattern for churches.

7 BENEFITS & LIMITS

Benefits of the method, and here we mean of the modelling bias itself, and of the visual tools developed, can be shortly summed up:

- Allows performing reasoning tasks on the evolution of an artefact as a whole.
- Allows performing reasoning tasks on feature changes inside the artefact, and on relation they may have to the evolution of the artefact as a whole.
- Allows comparing changes on an artefact to the evolution of neighbouring ones (in space, in history, in function).
- Helps performing reasoning tasks on the evolution of artefacts even when only qualitative information are available on their morphology.
- Allows non-ordered integration of new pieces of information.
- Does not imply a strong competence in computer solutions.
- Helps to uncover causal relations.
- Fosters cross-examination of divergent interpretations (and thereby discussions on how to interpret historical evidence).
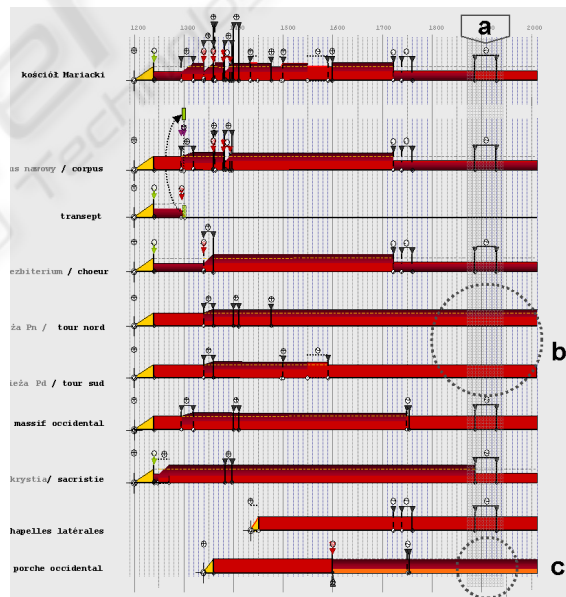

Figure 12: Top line, diachrogram for St Mary's basilica seen as a whole and underneath, diachrograms for each of its sub-parts. Note, vertically, and underlined by a greyish background under arrow a), how the neo-gothisation change does not propagate in b) (the two already gothic towers) and in c) (the baroque portal): artefact changes must be read at different scales.

- Helps underlining tendencies, patterns, exceptions – in variations of individual features

of artefacts, in variations of types of artefacts, in variations of artefacts at a given time slot, or in a given geographical area.

- Uncovers lacking, inconsistent, contradictory pieces of information.
- Can be adapted to various spatial granularity. What the artefact is, as a whole, is NOT the sum of what its parts are, accordingly artefact changes must be read at different scales, each of them corresponding to alternative sets of information (Fig12).

It is clear that a number of limits also need to be quoted, starting with technical ones. Our implementation is fundamentally a *simple* one. More needs to be done in order to implement the *context + focus* principle – at this stage basically a zoom+pan solution. Comparison mechanisms, and switches between spatial granularities also require further developments.

But beyond these technical limits, it is important to mention more fundamental issues, on which our attention is today drawing:

- The time granularity issue – Our unit at this stage is a year, which is a rather thick granularity. But the real problem is not to go down to a granularity of for instance a day: the problem is that the dating of historical events varies in nature and in precision. The initial indication we handle may for instance be "autumn of year YY", "first quarter of century CC", or "morning of day DD". Two challenges are therefore opened: on one hand developing a description model that would help us give more precision when possible, but that would also handle fuzziness; and on the other hand finding a visual solution that would remain consistent and yet offer alternative encoding depending on the nature of the initial indication.
- The context assessment issue – performing reasoning tasks about how artefact changes implies cross-examining sets of possible causes that would participate in the emergence of architectural consequences. A certain number of these causes have been identified and are already visualised. But a number of patterns of evolution are connected to the emergence of a more general "context" – cultural influences, wanted or unwanted presence of foreign powers for instance (Fig. 13). This general context may help underlining patterns, but it may also help rethinking the initial data set, with for instance the nomination of a new Bishop helping to date with more precision changes on a church for which we have poorly defined temporal information.

In addition, the evaluation procedure we have carried out is undoubtedly a limited one. Accordingly, future works will focus on evaluating the framework through more cases and granularity, on developing better context + focus mechanisms, and on time granularity / context assessment issues.
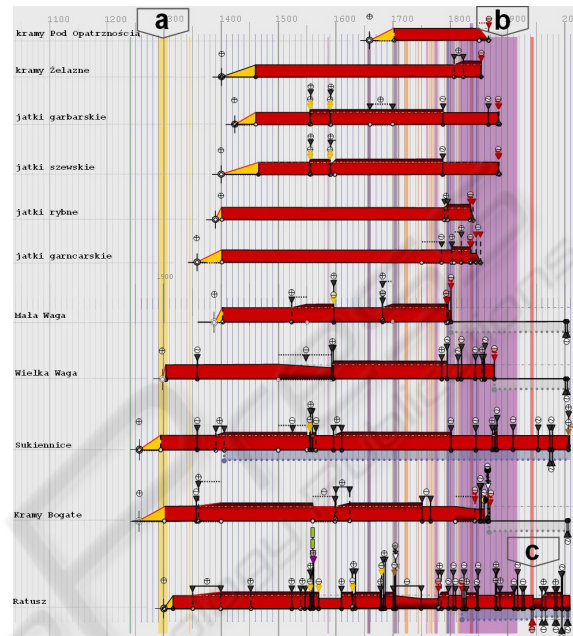

Figure 13: Context assessment helps decoding patterns – vertical arrow a) corresponds to the Czech presence in Cracow: a period of development of public edifices (four bottom lines. Vertical arrow b) corresponds to the Austrian occupation of southern Poland – a period of massive extinction on the main square. In c), period corresponding to a German presence in Poland, a portion of the town hall's unused underground structures (segmental anaesthesia – visible on the diachrogram under the time axis) is destroyed in order to build an underground cistern.

8 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. The framework meets two principles for the analysis and presentation of data quoted by (Tufte, 2006): *show causality, mechanism, explanation, systematic structure* and *integrate evidence*. The evaluation, although limited, does provide useful indications:

- The framework is usable by non-specialists, with a fast learning curve,

- It allows information uncovering and delivers domain-specific notions (uncertainty for instance).

  It will however be necessary to try out the framework at other scales before concluding on its possible extension. Beyond limits reported in section 7, the framework also has more general limits, inherent to the modelling choices made:

- Requires a good analysis of the artefacts before making any sense, implies to thoroughly describe the evidence (including by uncertainty "measurement") and therefore is of little support in the early phases of investigations.

- Assesses causal relations, it orders in time sequences, events, consequences, but it only does that. The disposal is a one-dimensional narrative disposal: it does not replace spatially and dimensionally determined disposals, as mentioned in (Dudek and Blaise, 2008) and experimented in years (see for instance Blaise, and Dudek, 2007). Our contribution should not be seen as an end, but "yet another mean to perform reasoning tasks" about a data set.

Given these precautions, the results we report show that visual thinking can fruitfully apply to the assessment of architectural changes. They also underline an ongoing research issue in most historical sciences: the necessity to better combine space-oriented visual disposals (cartography, 3D models, etc.) and time-oriented graphics (timelines, ribbon maps, etc.).

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