EXPERIMENTING TIMELINES FOR ARTEFACTS ANALYSIS: FROM TIME DISTRIBUTION TO INFORMATION VISUALISATION

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ABSTRACT:

When studying heritage artefacts, it is important to understand, communicate and cross-examine indications about how they evolved through time. Changes occurring in the artefact's morphology or functional role, once properly described and distributed in time, can be represented using linear graphics called timelines. Timelines have been, before and within the computer age, a classical and easy to understand visual support enabling the representation of a chronology, with in a number of examples a parallel reading of heterogeneous indications (historical context, cultural context, major dramatic events, etc.). In this paper, we first propose an overview of various types of timelines, applied to the analysis of architectural changes. We then introduce real-case experiments in which timelines are designed not only as a time-distribution representation, but also as information visualisation tools. The experimental set covers over 700 transformations within the urban centre of the city of Kraków. These experiments present the benefits of alternative graphic disposals that allow comparative and analytical readings of indications about artefacts changes, and can ultimately enhance information uncovering.

1. INTRODUCTION

1.1 The issue, the objective

When studying heritage artefacts, it is important to understand, communicate and cross-examine indications about how they evolved through time. Changes, if one reads them as consequences, imply that causes can be identified, and if not at least investigated. In other words, better understanding the evolution of artefacts though time can strongly benefit from trying to sort out indications we have for every relevant time slot, making clearer relations between possible causes (influences, events, etc.) and plausible consequences (architectural changes).

Changes occurring in the artefact's morphology or functional role once properly described and distributed in time, can be represented using linear graphics called timelines. Timelines have been, before and within the computer age, a classical and easy to understand visual support enabling the representation of chronologies. In a number of examples, they allow a parallel reading of heterogeneous indications (historical context, cultural context, major dramatic events, etc.).

But when looking at the very nature of the indications we handle when dealing with heritage architecture (uncertainties, lacking data, typology, duration, extent, causes of changes as far as architecture is concerned, etc.), there could be much more to timelines than a time-distribution of key moments and/or of indications. In short, when studying heritage architecture, we do not distribute in time "numbers" identifying key dates, but a set of complex, interpreted indications about changes.

This paper's claim is that, when dealing with heritage architecture, data can be distributed in time *using visual means*, and thereby fruitfully help understanding changes. E.R Tufte's masterpieces (Tufte, 2001, 2006a, 2006b) will convince anyone that *using vision to think* clearly applies to spatio-temporal data sets. And to architecture, specifically?

A number of solutions do exist, with some of the best dating back to XVIIIth or XIXth century with W.Playfair, E.J Marey or C.J Minard (pioneer of thematic cartography) presented in Tufte (2006a) or (Friendly, 2006). Do computers also help? In his analysis of Minard's contribution to statistical graphics, M.Friendly (Friendly, 1999) writes "*Minard almost invariably chose accuracy of data over the tyranny of precise geographical position when conflict arose*". In other words, it's the information that matters, not the mechanics or paradigm behind the representation. And so we will not focus on computer-based timelines only, although we will quote some of their pluses and minuses.

The aim of our contribution is to underline (through references to related work first, then through our own experiments) the variety of roles that timelines can have in fostering a better understanding of the evolution of architectural edifices or sites. We hope to demonstrate that beyond distributing items in a one axis visual disposal, timelines can also fruitfully act as:

- visual interfaces, allowing interaction with third-party data sets,
- interactive disposals allowing a time-based browsing of items,
- information visualisation disposals, with an aim to amplify cognition (Kienreich, 2006).

It is important to note once again that aiming at these goals raises specific challenges when dealing with architectural heritage information: long ranges of time, uncertainties in the dating, importance of cross-borders influences, difficulty to differentiate and classify changes (those with some kind of effect on the architecture itself, those that do not have immediate effect but will have, etc.). We do not pretend to provide answers and ready-to-use solutions to all these questions; however this paper should contribute to highlight a research issue needing further investigation. I.Johnson's *rethinking timelines* project has opened the way, highlighting this concern on a generic level. We believe that a specific attention should be drawn on this issue in the field of heritage architecture.

1.2 Field of experimentation and structure of the paper

Since we have carried out investigations on the evolution of edifices in the urban centre of the city of Kraków for several years, we have chosen this test field in order to illustrate various real-case uses of timelines. We based this work on the observation that artefacts correspond to a sum of slots in space, and of slots in time. Consequently, we traditionally view artefacts as a sort of chain of items, with each item defined through a morphology (spatial identification) and a time slot. Each item can then be represented inside 2D/3D models corresponding to user chosen dates. But naturally, both the spatial and the temporal identification bears its uncertainties, due to the very nature of the information we handle (uncertain contradictory or lacking indications).
The experimental set covers over 700 transformations within the urban centre of the city of Kraków. All developments combine freeware technologies and standards web graphics (SVG/VRML).
In section 2, we propose an overview of various types of timelines, and further describe our field of experimentation in section 3. In section 4, we introduce chronologically a series of experiments we have had with designing dynamic timelines not only as a time-distribution representation, but also as information visualisation tools.

2. REPRESENTING EVENTS AND CHANGES USING TIMELINES: OVERVIEW AND CHALLENGES

2.1 Scope

A timeline is defined by the HarperCollins dictionary as a visual representation of a sequence of events, especially historical events. A wide attention is put on the issue of visualising time-related phenomena in the field of information visualisation (see for instance (Spence, 2001) or (Geroimenko, 2005)). As mentioned in (Dudek, 2007), a bridge can fruitfully be established between infovis practices and heritage architecture representation, not only as far as timelines are concerned. Still this discussion would go beyond the scope of this paper. Our presentation focuses on establishing roles and limitations of the solutions quoted, all of them using a straight linear metaphor (which is by itself a questionable choice, as mentioned in (Dürstener, 2006)). A number of resources about timelines can be found in (Friendly, 2007).

2.2 The basic timeline paradigm

2.2.1 Distributing events: Going through literature one can often find the word timeline used in naming what is in the end a list of dates, with only relevant dates shown. Naturally, we focus in this paper on visual timelines, and the above mentioned list-like visual disposal will be here named a "chronology" in order not to get confused.
Its graphic equivalent is the visual metaphor of a line, a classic and simple visual disposal where an axis represents the continuum of time. Along this axis, events and changes can be reported, although with a number of (often hidden) knowledge modelling issues (see Figure 1), in particular the time granularity problem, and the uncertain/contradictory dating problem.

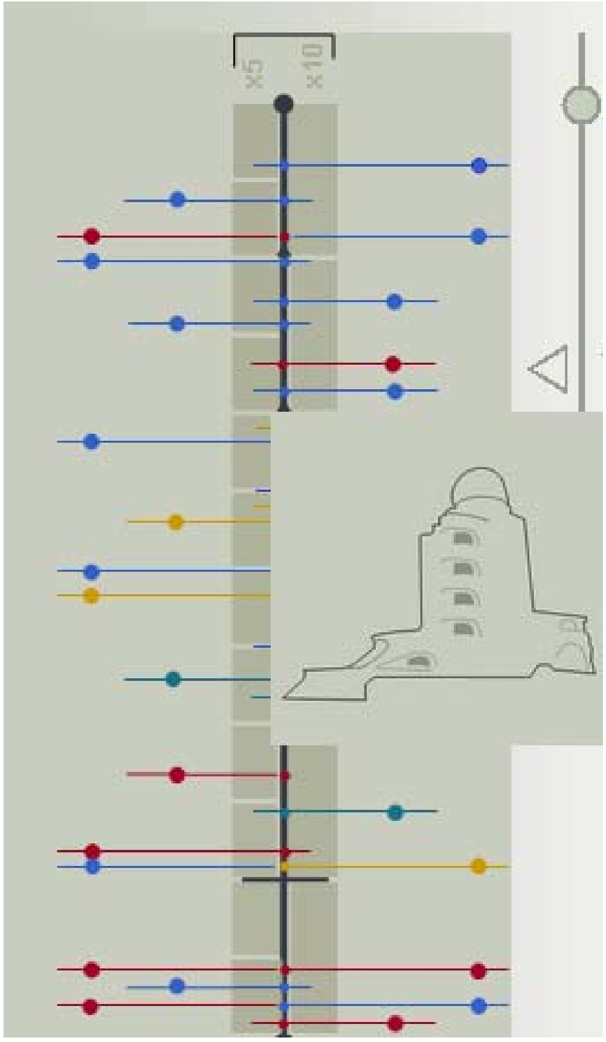
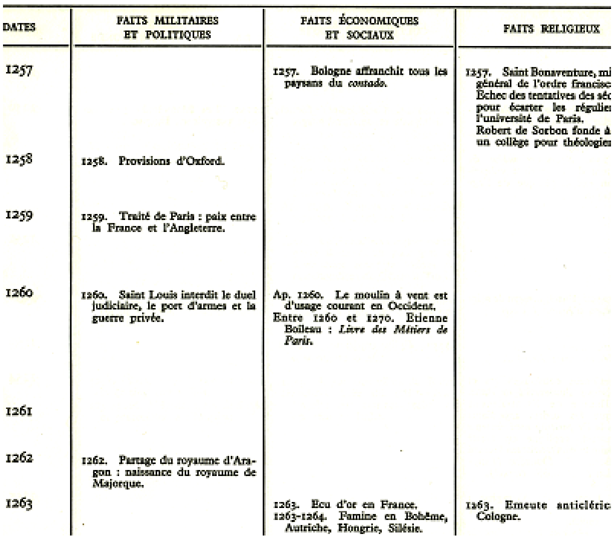


Figure 1: The UIA (International Union of Architects) XXth century architecture web repository timeline (A database of XXth century heritage edifices, www.map.archi.fr/UIA). Coloured lines and dots dispatched on the left and right sides of the line identify 48 reference buildings to which an edifice under scrutiny can be compared to (vertical line on the right). Brownish rectangles are used to query the database on 5 or 10 years intervals. The one year time granularity chosen here implies putting some reference buildings "on the same level" (coloured lines crossing the timeline), although several months can separate their construction.

2.2.2 Distributing events and correlating them: History is probably the domain where correlating events using a chronology has most widely been used. In the example shown in Figure 2, taken from the *civilisation of medieval occident*, a selected of so-called *facts* are correlated, in a list like manner..
A more visual example is given in Figure 3, in which (Koch, 1996) compares visually the periods covered by architectural styles in various European countries.
In these examples, the time axis acts as an integrator of events and / or changes, with variables expressed as parallel lines. In addition to knowledge modelling issues quoted in 2.2.1 (see for instance in Figure 3 the author's uneasiness with dating renaissance in France and Spain) such disposals introduce yet another challenge: finding the correct variables, and using a

limited number of variables so as not to overload the graphics. (A graphic like this in Figure 3, established for the European union, would require 27 parallel lines. Anything readable then?). Furthermore, magnitudes of changes are hard to depict, and multivariate data cannot be handled properly.



DATES	FAITS MILITAIRES ET POLITIQUES	FAITS ÉCONOMIQUES ET SOCIAUX	FAITS RELIGIEUX
1257		1257. Bologne affranchit tous les paysans du *contado*.	1257. Saint Bonaventure, mi général de l'ordre francisc Échec des tentatives des séc pour écarter les réguliel l'université de Paris. Robert de Sorbon fonde à un collège pour théologie
1258	1258. Provisions d'Oxford.		
1259	1259. Traité de Paris : paix entre la France et l'Angleterre.		
1260	1260. Saint Louis interdit le duel judiciaire, le port d'armes et la guerre privée.	Ap. 1260. Le moulin à vent est d'usage courant en Occident. Entre 1260 et 1270. Étienne Boileau : *Livre des Métiers de Paris*.	
1261			
1262	1262. Partage du royaume d'Aragon : naissance du royaume de Majorque.		
1263		1263. Ecu d'or en France. 1263-1264. Famine en Bohême, Autriche, Hongrie, Silésie.	1263. Emeute anticléric Cologne.

Figure 2: A partial view of (Le Goff, 1967) chronologic charts, with a classic correlation established between military and political facts, economic and social facts, and religious facts.

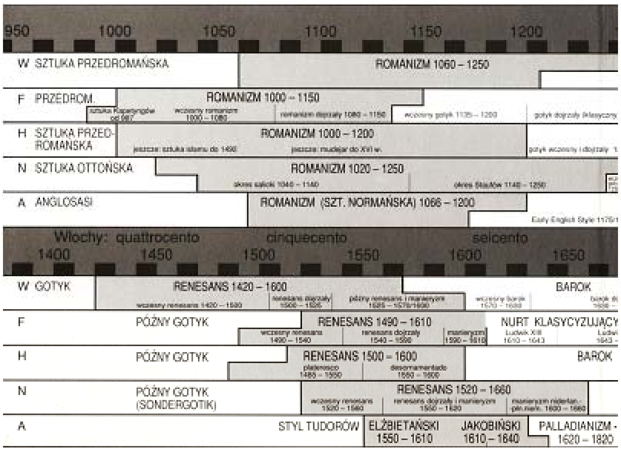


Figure 3: A partial view of (Koch, 1996) chronologic charts, focused here on the appearance of the renaissance style in Italy (line W), France (F) , Spain (H), Germany (N) and England (A).

2.2.3 Distributing and correlating events and periods, cross-examing information:

It is often necessary to distinguish events and changes with a short duration, as opposed to what we will call periods, with a long duration. Events and changes would then be depicted by visible, quantifiable results, whereas periods would serve as depicting the context leading or resulting from the events and changes.

In the example in Figure 4, symbols are used to mark events and changes (revolutionary outbreaks, constitution, intervention) whereas lines identify periods.

Another example are the generic timelines proposed by the MIT's SIMILE project (Simile, 2008), a must in terms of technology, but a disposal that is based on the very same concepts.

Events and periods are distributed along an axis, with some interaction to allow querying of events reported. The limitations noted in 2.2.1 and 2.2.2 apply here as well.

In other words, it's the mechanics or paradigm behind the representation that matters here, not the specificity of the information. This naturally raises an open debate.

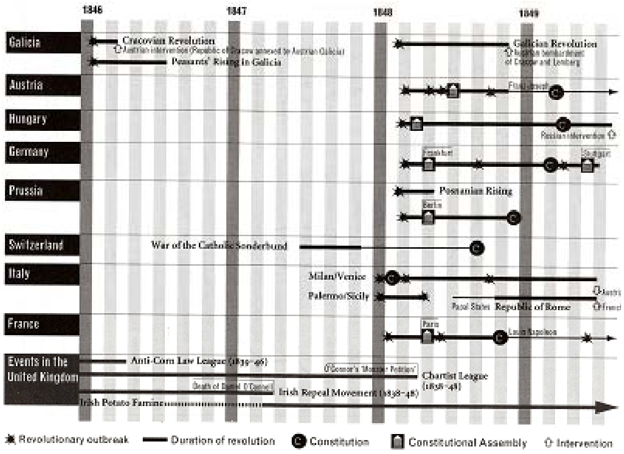


Figure 4: A brilliant visual comparison of revolutionary outbreaks in mid XIXth century by (Davies, 1997).

2.3 Timeline, timebands, time charts.

According to (Dürstener, 2006), a timeline is a one-dimensional graphic (with temporal flow depicted by a line), and a timeband is a two-dimensional graphic with one dimension used to represent time and the second to represent a magnitude associated to the events represented. Generalising even further, timebands / time charts may include in a two-dimensional graphics other variables, like in the splendid chart (Figure 5), taken from (Tufte 2006a) in which W.Playfair associated three variables (or time series) :

- price of wheat,
- weekly wages
- reigns of British Kings and Queens.

In this example, rules for reading the graphics remain simple: time flows from left to right along a line, although more information is available than in basic timelines. In other words, time charts do not imply a shift in paradigm, as examples in section 2.4 will.

Time charts are easy to read; they usefully enhance comparisons, cross examination of indications, and allow for magnitude assessment. However the design of efficient time bands or time charts is often neglected (and users of Gantt diagrams will for sure acknowledge they can be a dreadful bore).

Two challenges are raised: carefully choosing the relevant variables of course, but also organising to the best the representation itself. Tufte's rules for graphic design (Tufte, 2006b) provide here a good methodological basis. Undoubtedly, the use of time bands and time charts could be more widely developed in the field of architectural heritage information, as it is in the field of information visualisation.

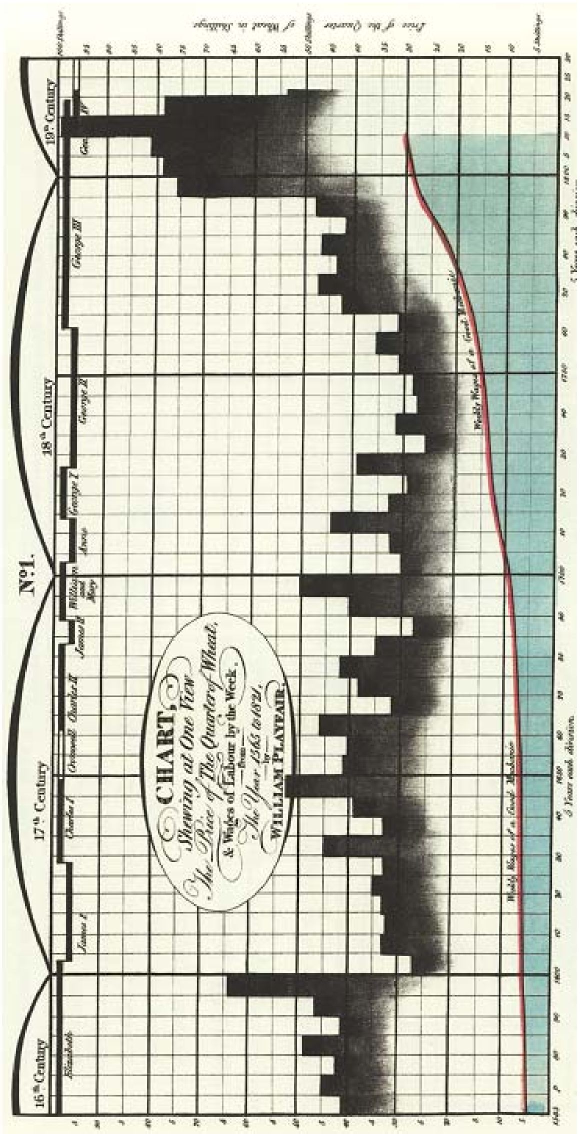


Figure 5: W.Playfair's time chart correlates three variables, observed through five years divisions, between 1565 and 1821. Blue curve: average wages, black polygons, price of a quarter of wheat, top line, King/Queen.

2.4 Time distribution, and space: an open challenge

Timelines (and related) have proven efficient solutions for chronology assessment and information correlation in various fields of experimentation, notably in history naturally. A number of researches are carried out in order to further develop them, to start with in the field of information visualisation.

Although this aspect goes a little beyond the scope of this paper, we would like to conclude this section by showing that the most complex and also challenging research issue is on how to better combine time+space representation. Readers will of course understand that when dealing with architecture, neglecting space is nonsense. But the concern we raise here also exists in other fields, and of course in history, as shown by the example in Figure 6. In this case too, the objective of the graphics is to provide indications on a chronology. But the shift in paradigm is such that the reading of the graphics naturally over-emphasises the spatial nature of the phenomenon. Time is read once space is understood, and relative durations are hidden, with consequences on limits to the amount of variables that one can possibly handle, as clearly established by J. Bertin's graphic semiology (Bertin 1998).

Figure 6: Evolution of the polish borders under King Bolesaw Chrobry – with arrows marking movements. Understanding the chronology is less obvious than the spatial aspects. (Trąba, 2005).

Timelines are linear, and the succession of events is quasi-obvious. But when representing architectural changes over time using spatial representations (a constant concern since XIXth century authors major works on the history of architecture), time can only be represented using Bertin's graphic variables, and thereby cannot be easily read as a succession. The layer paradigm, implemented both in GIS platforms and in CAD tools, does provide a very basic mechanism that allows simulating successive states. But there is more to time passing by than a succession of layers; and concepts like magnitude or density of changes that one can handle layer by layer, cannot be chained in a single, time-based representation. In this convincing example below (Figure 7), a comparison is established between cities of the western provinces of the Islamic empire during the medieval period. Colour is used as the graphic variable representing time, and various symbols identify parameters observed (presence/absence of edifices, role of city). Although synthetic, and rich of information, the disposal can hardly compete with a timeline when trying to read a chronology.

Figure 7: An efficient spatial distribution, but a rather uneasy handling of time. How long does it take the reader to say which city was best developed during the XIIth century?. (from Encyclopedia Universalis – Le grand atlas de l'architecture mondiale, France 1998).

Pointed out by M.Friendly (Friendly, 1999), C.J Minard introduced yet another method of combining temporal and spatial data in a single graphics: the figurative maps.

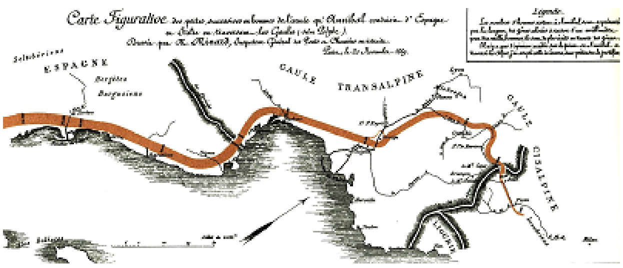


Figure 8: C.J Minard figurative map showing losses in Hannibal's army during its trip from Spain to Italy .

C.J Minard's figurative maps can be understood as an interpretation of the concepts of ribbon maps, nicely described by I.Calvino as narrative maps. A well-known ancestor of ribbon maps is The Peutinger map of Roman routes, a map that has its equivalents in numerous societies across the planet, as demonstrated by I. Calvino (Calvino, 1998). Ribbon maps compel space to time: they represent in a 2D space the time needed to go from point A (x1,y1) to point B (x2,y2) with distance (A1,A2) representing a duration and not a length.
C.J Minard's figurative maps differ from basic ribbon maps in that a metric geography is respected, with a temporal, evolutive, ribbon-like phenomenon projected on this geography (see Figure 8). How to think out and implement efficient ribbon maps or figurative maps is undoubtedly today *terra incognita*, but could be a fruitful research direction. However this anticipates some of the concluding remarks of this paper.

3. FIELD OF EXPERIMENTATION

In the SIMILE project, a generic all-purpose timeline formalism is proposed. Why do we bother, then? Why do we believe this could be a questionable solution in our research context? Well, because our experiments on the city of Kraków have shown us that timelines may have different things to assess, and may require different visuals *displays of evidence* as E.R Tufte says it (Tufte, 1997). However the reader may not take this for granted. So, before presenting timelines themselves, we need to better present our field of experimentation.

3.1 The city of Kraków

Former capital of Poland, the fourth largest city in Poland, Kraków has one of the best-preserved medieval city centres in Europe. The layout of the old town is a result of successive additions and of the evolution of various urban structures – initially the ensemble of the Wawel Hill, the suburbium called Okół and the medieval town located in 1257 (sse Figure 9).
On the territory of the Unesco-listed part of the town a big number of architectural monuments remain, coming from all periods and styles from Middle Ages to the present. The urban layout of the city did not change a lot since the medieval period, although individual edifices may have been transformed. The area of the town is surrounded by a parkland green zone arranged in place of former fortifications (see Figure 10). The fortifications as well as trade buildings of the market square were victims of the XIXth century organisation and tidiness ideas. In 1684 forty-seven flanking towers were defending the town.

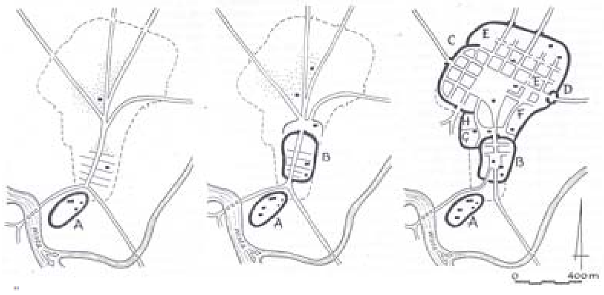


Figure 9: Kraków, the three earliest phases of urban structure's evolution (S. Bobiński, 1975).

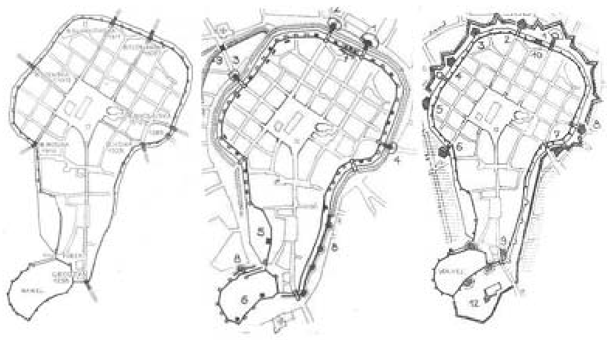


Figure 10:Kraków, development of the system of fortification – XIII/XV, XV/XVI, XVII according to (Bogdanowski, 1977)

Years of conservation actions, examinations and research conducted in this place produced a very significant quantity of various documents (descriptions, analyses, drawings, photographs, maps, reconstructive hypothesis, paintings, …) that should be gathered, organised and visualised. Naturally, analysing and understanding artefact changes in such a context requires the cross-examination of various indications, and sources. It is clear that in the case of Kraków the risk is to become unable to sort out and interpret usefully sources.
And so the challenge here is to retain through visual means the artefact's documentation analysis, and provide graphic tools to reveal it. As demonstrated in J.Bertin's "graphic semiology" (Bertin, 98), attempting to exploit the spatial distribution of data sets raises numerous methodological questions about the efficiency and the readability of graphics. In response, we have tried to adapt ideas and methods from the field of information visualisation to the architectural heritage, where in addition the uncertainty of the sources handled poses specific problems (Dudek, 2007). But attempting to exploit the time distribution of data sets is also a challenge, and this contribution shows where we stand in developing graphics for representing time, and where we stand in connecting them with spatial representations.

3.2 Method and objectives of our investigations

We consider that the best way to visualise, access and analyse the data related to the architectural and urban heritage is to use architecture itself as a mean to interface pieces of information, (see Dudek, 2007b). Our investigations therefore base on the premise that shapes act as a media allowing the integration of the above mentioned heterogeneous clues. Consequently, they may enable information visualisation and retrieval through 2D/3D dynamic graphics. Such clues, in other words the artefact's documentation, vary in type and relevance, and are clearly at the heart of any historical investigation about artefacts changes. They are notably used in order to understand their morphological evolution, and can help researchers to represent its successive spatial configurations. In order to do so, an analysis of the documentation is carried out that helps putting in relation pieces of architecture at various scales (from details to edifices) and pieces of information. This naturally opens an opportunity to use the artefact's representation as a mean to retrieve/visualise information, as shown in (Dudek, 2007b).

It has to be stressed that, in any investigation of an historic artefact, the analysis of sources is duly done by scientists. Therefore the method presented here is not about going through sources in order to establish a document(s) <-> artefact(s) relation, but to retain this existing work, and to give tools to visualise it. This is done by handling four sets of tools/formalisms/data sets:

- An architectural ontology (implemented as a set of classes in the sense of OOP) handles the artefact's morphology. Each class is given methods that enable the instance to represent itself in SVG/VRML or to write an XML record file storing its morphological description. Various evolutions of an artefact are represented as a chain of instances, allowing the system to handle morphological and documentary changes through time.
- A relational database (VIA) stores for each instance descriptive criteria such as typological specificities or alternative denomination, with a focus on the representation of levels of certainty (to which extent can we say this artefact was there at that time ? Who said so? Is this author credible?)
- A relational database (SOL) stores data about documentation and archival documents (traditional editorial details, physical format, etc.) This first level of description of the documents bases on the Dublin Core recommendation. More important here, each document can be connected to one or several instances of the VIA DB, allowing cross-querying of DBs.
- A set of classes (in the sense of OOP) produces in real time the graphics needed to represent the artefact at any time of its evolution. They output web-enabled formats, XML/XSLT, SVG, VRML. These graphics, may they be 3D or 2D (see Dudek, 2005), are therefore supposed to help users cross-examine the various pieces of knowledge they handle.

During these investigations, both architectural and urban elements of the town's construction, their evolutions (897 evolutions of 385 objects) as well as related historical sources (791 sources) have been described. These numbers remain very little compared to other experiments, or to the city itself. However they imply that we picture our work not only as putting studies one next to the other, but as handling individuals on one hand, and handling a collection on the other hand.
In other words, with such a number of edifices and sources, it becomes necessary to try and get an overall view of changes, and more globally provide means for context assessment. A collection of items becomes more than the addition of its components if it provides its own set of information. Accordingly, dealing with such a collection opens an opportunity to try and uncover new information by proposing efficient comparative disposals. And this is where a variety of timelines, as will be shown, have been considered as necessary.

4. FROM TIMELINES TO INFOVIS

4.1 The first disposals

When we started studying Kraków's urban centre and its development, we soon faced the necessity to show how the morphology of edifices changes through time. Accordingly, we developed an ad-hoc timeline, nested as an interactive command inside 3D VRML scenes. This timeline, shown on Figure 11, allows users to move to and fro the foundation of the city interactively, with each element in the 3D scene modified accordingly. The content of the scene is itself a user selection.

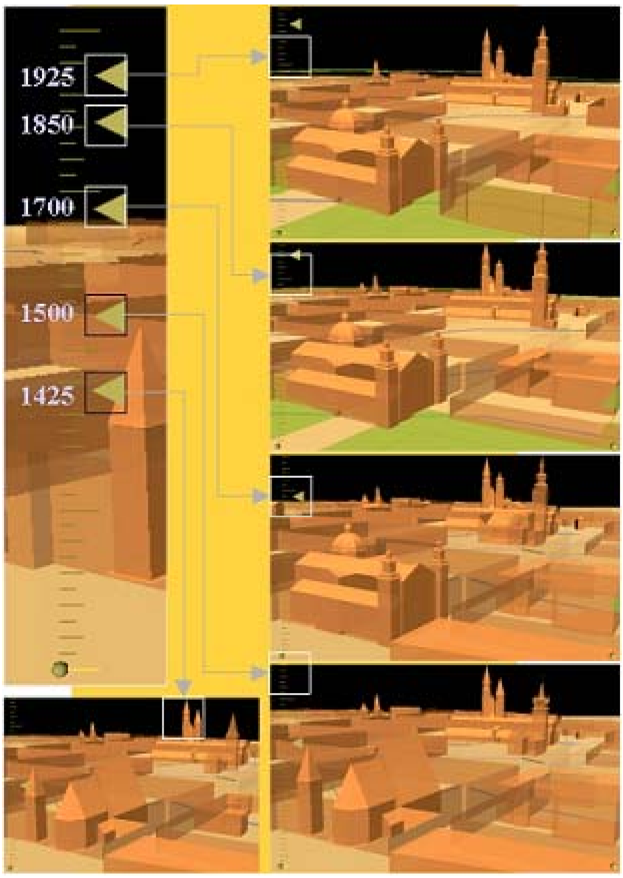


Figure 11: Screen captures of five moments in the development of the city, with in the foreground the noticeable change of orientation of Saint Anne Church. Note, left, the timeline itself, a basic one if any.

Besides a time granularity problem (one year intervals only), this disposal left us unsatisfied, since it allowed only a strict sequential browsing (no comparison possible between evolution 1 and evolution 5 for instance). It in fact did not much more than underlining what we already new. So another disposal was tested, still in connection with a spatial representation: an interactive cumulative representation of changes (Figure 12).

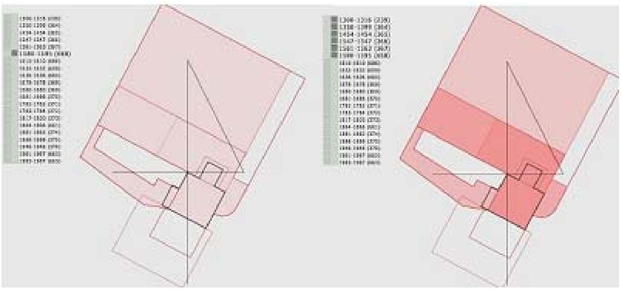


Figure 12: An SVG cumulative representation of changes on the case of Krakow's old town hall: left, the user selected period of foundation and contemporary period, right, the user selected all changes during the renaissance period.

4.2 One step beyond: an infovis perspective

4.2.1 Correlating architectural changes and level of documentation:

The documentation's analysis helps researches justify choices they make when describing how an artefact evolved throughout its history. It is therefore most important to find visuals means to put in parallel the chronology of evolution of the artefact, and the chronology of the sources in order to track lacks (i.e. moments of the artefact's history for which we can find no relevant source).
In the recent experiment shown on Figure 13, we developed a timeline that for each object under scrutiny allows the user to compare on two parallel lines :

- the periods of change of the object,
- the amount and periods of relevance of documents about those changes.

The timeline acts as a user-monitored layer on top of a 2D spatial representation of instances, dynamically produced in SVG. The timeline is linked with two other disposals, a certainty assessment wheel and a visualisation of documents types (differentiating books, maps, etc.).

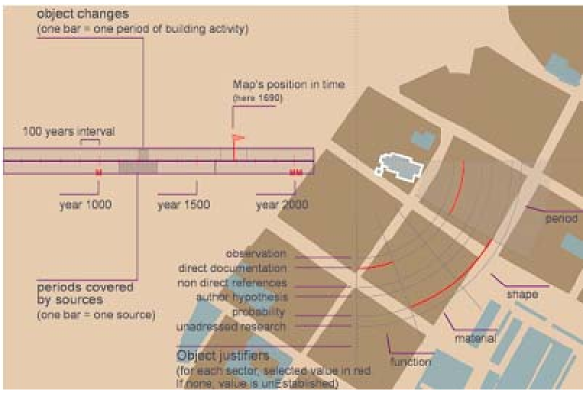


Figure 13: Legend of elements of the disposal. Note, (bottom part of the timeline) the dark grey, rectangles correspond to periods of relevance of documents; (top part of the timeline) rectangles correspond to object's transformations. On this rather simple object, correlation is good for the first period of changes, but poor for the two next.

4.2.2 Visualising densities of changes:

Once a collection of objects has been studied, it becomes possible to try and point out patterns of evolution, notably in order to underline moments of strong changes *vs* moments of relative stability, or in order to underline differences in the density of changes of various types of objects. Accordingly, we have an implementation of the above principle, shown in Figure 14 and 15, where each period of change for each object in the user's selection is represented by a horizontal gradation on the global vertical timeline.
This disposal's first objective is to allow a visual investigation of densities of changes. But it can also be used in order to mark differences between types, and thereby uncover different patterns of evolution. Although this disposal is somehow questionable from the point of view of readability (especially when reproduced on a sheet of paper like here), it clearly goes one step beyond our initial experiments with timelines. In line with an information visualisation perspective, it acts as a tool for thinking, uncovering new information.

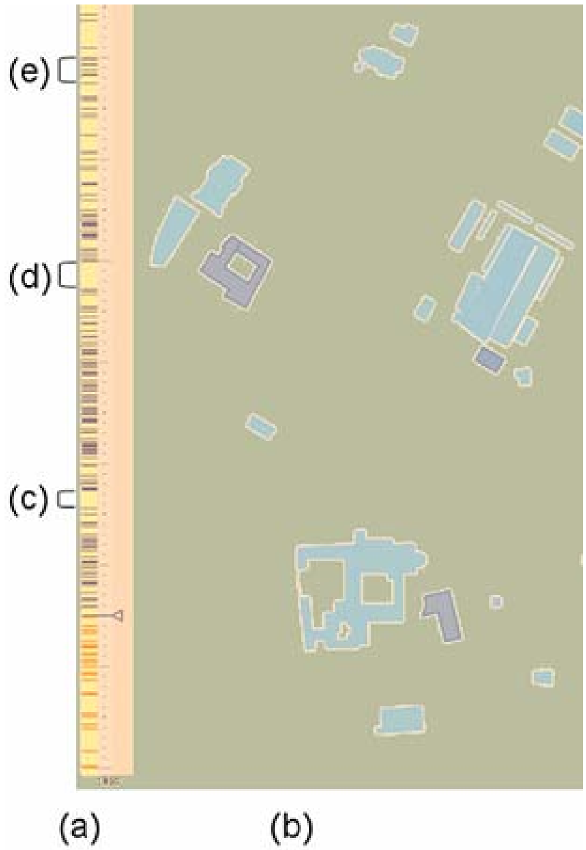


Figure 14: **(a)** the timeline itself, with its interactive triangular cursor (here on year 1850); **(b)** the user's selection (main edifices) are shown in their evolution for that period. Note questions raised by reading densities of changes, **(c)** a remarkable absence of transformations for monumental edifices between 1725 and 1745, most likely due to a succession crisis and a related war; **(d)** same absence of between 1500 and 1530, less easy to explain, thereby opening a question for interpreters; **(e)** an early and strong period of transformations, under the influence of Czech kings reigning in Poland at that time.

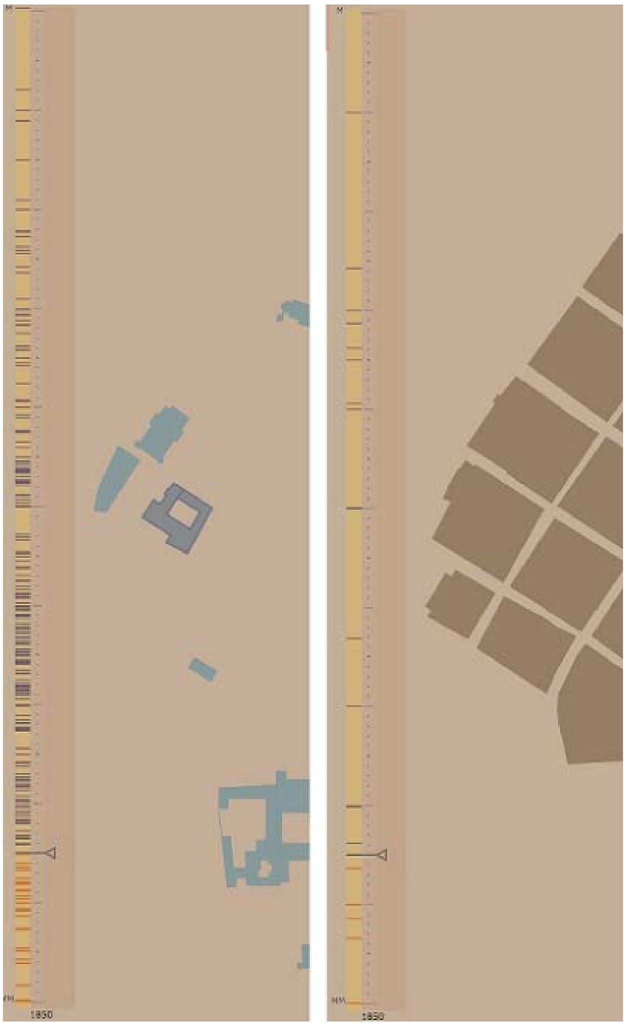


Figure 15: A timeline and an information visualisation disposal. Each horizontal bar corresponds to a change in one individual inside the collection. The arrow is an interactive cursor monitoring the content of the 2D map (orange lines mark periods the user has not yet visualised). Note differences in densities of changes between, left, density of changes of major architectural edifices and, right, of urban blocks.

5. CONCLUSION

Researchers and practitioners can today fruitfully use basic timelines, that have proven efficient (notably because of a very limited cognitive load for users). But, surprisingly, very few fundamentally new visual disposals have been designed since the Information Technologies shift that would better match the reality of heritage investigations.
Indeed, the adoption new visual disposals as “tools for thinking about chronologies” implies tackling several issues: enabling variable granularity of time scales, reading densities through time distribution, representing lacking/questionable indications, cross-examining changes inside semantically consistent sets of artefacts, combining the reading of individuals and of collections, etc. And our contribution does not pretend to cover all these issues. It however shows that, if designed in an information visualisation perspective, they can go beyond distributing events in time, and provide grounds for information uncovering. Accordingly, although the results presented here remain early stage results, they show it can be worth further investigating time visualisation methods and formalisms, in particular when working in historic sciences.

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