Informative modelling: towards 2D/3D visualisation of architectural evolutions

J.Y Blaise, I.Dudek
UMR CNRS / MCC 694 MAP

Introduction

With the development of NICT (New Information and Communication Technologies) researchers and professionals involved in the study of architectural heritage are faced with a plethora of solutions and modelling languages the durability and effective contribution of which are sometimes questionable. The changes in practices that they impose and the necessity of adaptation to them open both opportunities and challenges.

Since, whether we like it or not, the study of built heritage is largely anecdotal when faced with current major scientific issues[1], researchers and professionals in this field have to rely on themselves to develop tools, methods and practices adapted to their subject.

At the centre of our work there is therefore not a scientific discipline or a technology, there are architectural artefacts, buildings, groups of buildings, and parts of buildings as left to us by time. Our objective is to understand the origin of these artefacts and their evolution over time. Our aim is not therefore to illustrate the advantages of a particular technical solution, but first and foremost to consider the appropriateness of these solutions to the often complex specificity of the study of heritage artefacts.

What choices and constraints need to be considered when opting for a particular tool? What is the cost of these choices (obscuring of doubts, standardisation of observations, doubtful long-term interpretation of results, etc.)?

Before making this choice of tools and formalisms, we propose to carry out a methodological investigation with the aim of bringing the study together around its subject (heritage artefacts and their evolution). Artefacts and information become mutually dependent, the representation becomes a tool for visualising information, a “work and discovery” tool in the words of J. Bertin[2].

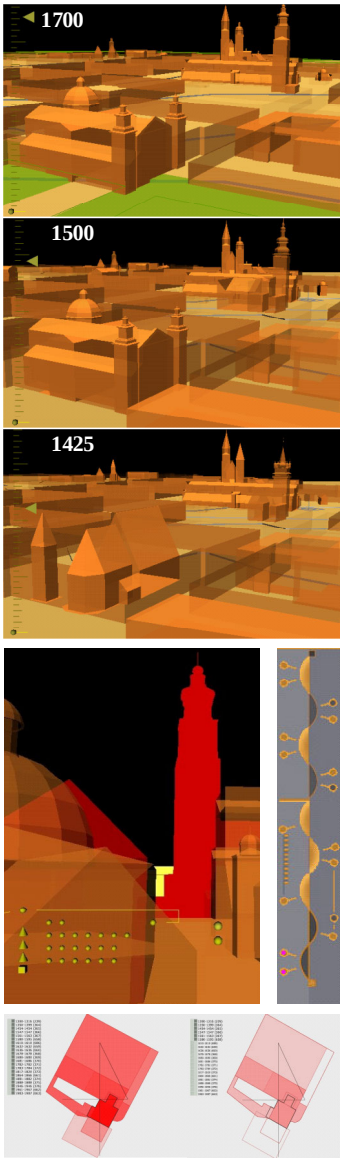

Fig. 1: *Adapting our graphic practice to an information visualisation approach. Top, typochronological analysis Centre, left, colour coding for information layering Centre, right, visual spiral marking study progress. Bottom, visual chronological layering*

[1] Evidence for this can be found in the fact that the notion of built heritage is not cited among the 199 themes of the “Starting Grant 2007” call for projects launched by the ERC (European Science Council) under social sciences or NICT.
[2] J. BERTIN, « *Sémiologie graphique »,* Éditions EHESS 1967/1991

As an answer, we introduce a methodological approach that we call *informative modelling*, at the intersection of NICT and multi-layered analysis of heritage artefacts[3].

Informative modelling can be defined as a methodological framework with an aim to represent spatialisable and changing knowledge manipulated when studying artefacts and their evolution. It aims to bring together artefact modelling and information visualisation.

Two questions lie at the heart of the matter:

- how can we better understand and document the evolution of heritage artefacts;
- how can we communicate this by visual means.

As a methodological framework, informative modelling is also a method of self-questioning on how to conduct a diachronic study of an architectural artefact (at a time when studies are led more by computer solutions than by ourselves). This practice is formalised by a series of "rules" and practically implemented through case studies, two of which will be presented, the first focusing on the use of 3D imaging, and the second using spatialised and/or abstract 2D imaging.

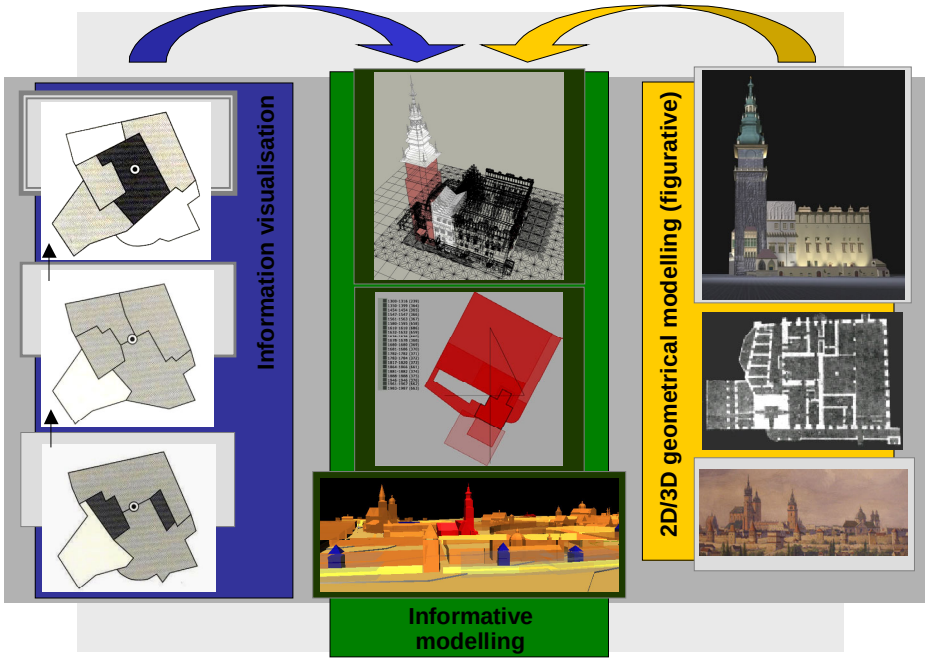

Fig. 2
Informative modelling, an approach inspired by two legacies. Left, an example of spatial redistribution of data cited by E.R Tufte (graphic analysis of deaths during the 1859 cholera outbreak in London, the circle represents the well finally identified as the cause). Right, tradition of figurative architectural representation in which morphology dominates.

[3] This article uses in part defining elements of this approach published in J.Y. BLAISE, I. DUDEK, «Modélisation informationnelle : concepts fondamentaux- Visualiser pour raisonner sur des connaissances architecturales », Journal MIA Vol0, <http://www.map.archi.fr/mia/journal/articles/vol0/num1/blaiseDudek.pdf>

Current Situation

The study and understanding (including visual) of heritage artefacts, whatever spatial granularity[4] is chosen, is based primarily on an in-depth analysis of documentary resources. The first aim of this analysis is to help understand the transformations of a particular building or group of buildings. Another possible aim is to put these "local" transformations into a broader perspective, namely the evolution of the art of building in general.
However, bringing together these clues poses significant management and interface problems, on account of the quantity of documents to be handled as well as of their considerable heterogeneity and often extensive distribution.

Moreover, due to the very nature of the documentary sources handled (uncertain, incomplete, originating from independent or even non-compatible tools), we must be able to ensure for each artefact a sort of documentary "traceability". Finally, providing visual evidence of these clues through 2D/3D models can lead to disorder and confusion due both to their quantity and to their considerable heterogeneity.

At the same time, in the field of heritage architecture, the virtual model is increasingly used as an effective popularisation tool. However, this type of graphic production raises a number of questions if the use of the 2D/3D virtual model is to be sustainable and well thought-out.

Two particular points can be mentioned:

- a lack of readability of the representations (inferences made for the reconstruction of the objects are obscured in the final image);

- a lack of efficiency affecting researchers themselves, who put time and means into producing scenes which remain an edge effect of their study (such scenes they do not give access to the deepest layers of information such as bibliography by object, typological or terminological entry etc). This type of representation is not linked to the sources justifying the content, it is not dynamically up-dated when new information is collected, and it does not even mention what is in fact the most important thing for the analyst – the uncertainty of the initial data.

Fig. 3
Graphic practices underline where we are in the knowledge acquisition effort, and the doubts we have. The bell-tower (the only part of the building left standing today) is clearly marked visually as not belonging to the hypothetical set of forms implemented in this reconstruction of the former town hall of Kraków.

[4] As described by H. MATHIAN, M. PIRON, "*Geographical scales of multidimensional methods of analysis*" (*Échelles géographiques et méthodes d'analyse multidimensionnelles)* [in] "*Spatial analysis models"* (Modèle en analyse spatiale), under the direction of L. SANDERS, Lavoisier 2001, pp. 61-103

On the contrary, in the field of information visualisation, the graphic is not only used to question the data but also to sort them. E.R Tufte's views about information visualisation much more closely matches our approach: "*we envision information to reason about knowledge, to document, to communicate and preserve this knowledge*".

The question of the role of the graphic is raised in many disciplines, but it has not yet been tackled as such in the field of heritage architecture. The use of graphics in our field of application is naturally not just limited to the production of 3D models, although these tend to obscure other solutions such as multi-layer 2D[5], or resorting to commercial CAD[6] software solutions combined with RDBMS (Relational DataBase Mangement Systems). However, it is clear that little work has confronted the question that interests us, namely, ***can architectural representation be used as a scientific visualisation tool***[7]? That aim is seen in the field of heritage architecture through individual initiatives such as the work of P. Alkhoven[8] on the town of Heusden, which shows us, if need be, that there is more to a graphic than décor.

Our goal is to bridge the gap between the above-mentioned practices, starting from the simple idea that the representation of artefacts does not necessarily have to aspire to a detailed realistic representation but must act as a dynamic interface in an information system. It should be used to discover information, and ultimately to understand both the artefact itself and the testimonies handed down by history concerning its origins and life.

Observations and hypotheses

Let us take as our starting point a very simple idea*: **in virtual models too, behind shapes there can be information***[9]**.** In other words, we say that architecture can be an integrator between the different sources manipulated.
Each shape has corresponding documentary evidence, specific to the time slot identified by the model. It acts as a vehicle/vector for sorting, visualisation and comparison in a set of information.

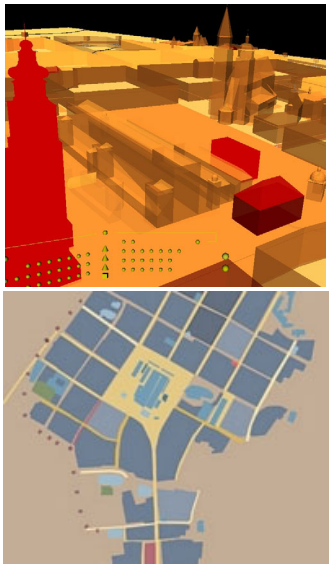

Fig. 4 *The model seen as an interface using 3D (VRML) and 2D (SVG)*

[5] *cf.* U. MÜLLER et al., "*Damage mapping of historical buildings"*, [in] proceedings of SFIIC days, *sine loco* 1997
[6] *cf.* S. NICKERSON et al., "*Computer aided recording tools help automate the creation of a site information system*", [in] CIPA symposium proceedings, *sine loco* 1997
[7] *cf.* R. SPENCE, *"Information Visualisation"*, ACM Press, *sine loco* 2001
[8] P. ALKHOVEN, "*The changing image of the city. A study of the transformation of the townscape using Computer assisted Design and visualisation techniques*", University of Utrecht, 1993
[9] A barely masked reference to the title of A. Kiner and F.Guénet's work « *La cathédrale : Livre de pierre* » Presses de la Renaissance, Paris 2004

The method we propose is thus situated at the intersection of the fields of 2D/3D geometric modelling and of information visualisation.

First of all, we made three simple assumptions:

1. the architectural corpus, the basic physical forms of the building, mediate between the information to be handled ;

2. as we will be working with objects which have either disappeared or changed, these forms will be little known and will be represented with a relevant level of abstraction;

3. in 2D or 3D models, the corpus is a browsing tool (allowing users to investigate sets of data or information element by element).

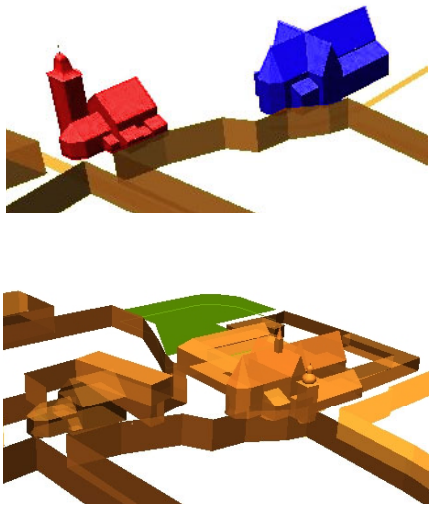

Fig. 5 The change in the quantity and quality of information about an object produces dynamically a change in its representation: one year separates the queries producing these two models.

These representations do not show us the "real" object, often poorly known, ***but how we understand it***. They are created dynamically in response to queries about available information:

- at time ***τ*** of the study ;
- in position ***λ*** (toponomy, architectural affiliation) ;
- at moment ***μ*** of the history (*e.g*. this place in 1455).

Accordingly, implementing such representations involves an overlapping of themes:

- taking into account uncertain and heterogeneous information;
- considering the evolution of our knowledge;
- producing (dynamically) 2D/3D graphics;
- adapting our practices to the specific realities of the heritage field (uncertainty should forbid graphic assertions, what is unknown should be highlighted rather than hidden, etc.).

Towards a multidisciplinary methodological framework

So could architectural representation be an ***investigation tool*** ? The answer is yes, as proved a careful reading of classic references such as C. Sitte[10] or A. Choisy[11].
They show that there is a way in between spatial modelling itself (geometric representation, multi-representations, multi-resolutions, etc.) and information visualisation (as described by E.R.Tufte[12], *i.e.* a visual explanation approach).

By virtue of the spatial character of artefacts – this approach calls for a more or less abstract representation of the subject itself in "real"

[10] C. SITTE, « ***L'art de bâtir les villes »***, l'Équerre, Wien, 1889
[11] A. CHOISY, « *Histoire de l'architecture »,* Tome1, Inter - Livres, France, 1991
[12] E.R. TUFTE, *op.cit.*

space. However, by virtue of the temporal and cultural character of the subject studied, the approach no longer calls for a representation of the subject itself but for our analysis of the subject, in other words, of the information available for understanding it.

Our approach, informative modelling, has its roots both in architectural drawing (*cf.* J. Cuisenier[13], D. Estevez[14]) and in graphic representation as a "*system of signs that humans have developed to retain, understand and communicate the observations that they need*", in the words of J.Bertin[15].

Over and above, *informative modelling*[16] is a cognitive approach[17]. Consequently, its scientific origins include modelling languages (knowledge visualisation, management of spatio-temporal data, etc.) and questions linked to the study of heritage architecture at different levels (information retrieval and management, nature of the hypotheses in historical sciences, etc.).

In short, it is a methodological framework concerned with building information-effective graphics through which a gain of understanding can be achieved. But once this is said, maybe it is time to ask ourselves in what can such a general framework be helpful to researchers. What tangible services can it offer?

As an answer, we have tried to identify a grid of rules that would act as safeguards helping researchers all along the research process to support their activity with sustainable and information-effective graphics. These rules are nothing more than a best-practice grid, but encompassing a wide range of issues: they are actually divided into four groups (information, models, representations, abstractions)[18].

These rules can thus be seen as a sort of check-list when carrying out a heritage study. However, our aim is also to provide a way of testing the approach itself, fostered by inter-disciplinary discussions at meetings such as the present thematic course "spatio-temporal dynamics in archaeology" or the "Visualisation summit"[19] day at which a programme to evaluate these rules by experience will be proposed.

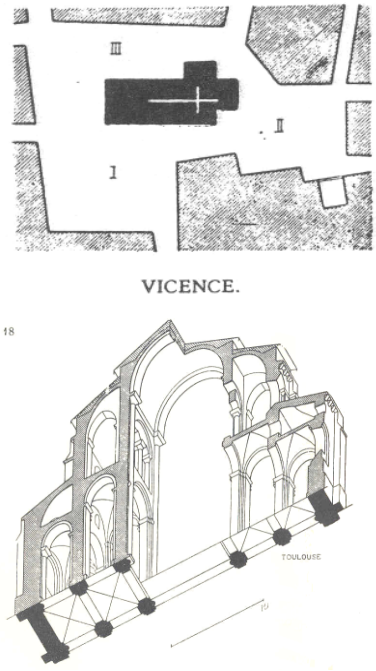

Fig. 6
Representation of the building: 3 examples illustrating the integration of spatial analysis and a search for visual explanation. Top, the famous "art of building towns" by C.Sitte (fig.16) Centre, taken from "The History of Architecture" by A.Choisy (p.212), a fine example combining 2D and 3D to illustrate what the author calls the "donnée auvergnate" on Saint Sernin de Toulouse. Bottom, extract from P. Alhoven's work at Heusden (op.cit, p.102); a 3D model used to situate 2D façade typologies in the town space at time T of its history.

[13] J. CUISENIER, « *La maison rustique; logique sociale et composition architecturale* », UF, Paris 1991
[14] D. ESTEVEZ, "*Dessin d'architecture et infographie"* CNRS Editions, Paris 2001
[15] J. BERTIN, *op.cit.*
[16] *cf.* <http://en.wikipedia.org/wiki/Informative_Modelling>
[17] *cf.* J.Y. BLAISE, I. DUDEK, « *Modélisation informationnelle : concepts fondamentaux ... », op.cit.*
[18] *cf.* J.Y. BLAISE, I. DUDEK, « *Une introduction à la modélisation informationnelle* », <http://www.map.archi.fr/mia/journal/articles/vol1S/num1/bookMia_fr.pdf>
[19] See *www.ia.arch.ethz.ch/summit.htm*

Experimentations

From the two examples below, we hope to illustrate our approach concretely through very different experiments.
The first case study is a programme carried out in collaboration with local partners in the town of Kraków (Poland), a long-term programme, which is now in its 7th year. This programme has two central priorities: first to structure and put to use heterogeneous data sets, and secondly to interface these data using dynamically constructed virtual 3D models.
The second case study is a short-term exploratory study about notably antique theatres (carried out as part of WP6 of the European STRABON programme) in the context of a so-called "cultural tourism" programme (admittedly more of a pretext than a central objective).

First example: towards an information system about architectural and urban heritage for the Internet, taking the case of the medieval centre of Kraków.

The city of Kraków developed significantly during the first six centuries of the second millennium, before entering a period of relative decline when the Swedish monarchs moved the capital of the kingdom to Warsaw. This relative decline constitutes an opportunity for us today, as the city experienced little significant change during the nineteenth and twentieth centuries compared to other cities of similar size[20].

Moreover, years of preservation and investigative actions have resulted in the production of a large quantity of documents (descriptions, analyses, drawings, photographs, plans, etc.) which need to be collected, organised and visualised.

The objective was thus to use information technologies for better management and preservation of the documentation, and ultimately for a better understanding of the urban ensemble and its elements. However, we were constrained by the need to allow collection custodians real control over the data that they manage (*i.e.* favour the use of technologies which do not entail the dependence of collection custodians on a particular platform). Moreover, we identified the need to develop our approach round formalisms for the Internet (thereby providing concrete solutions with regards to the question of the heterogeneity of the contents manipulated).

In short, this research underlines the variety of services digital models can provide, such as:

- knowledge visualisation;
- data browsing;

[20] Kraków historic centre is on the UNESCO Historic World Heritage list (since 1978), <*http://whc.unesco.org/en/list.29*>

- support for the phase of interpreting general knowledge and specific data, whereby the state of progress of investigation can be assessed graphically.

But at what expense was this achieved? Let us go back to the original problem:

a) from the standpoint of the representation: the model allows us to formulate what we know about the buildings in terms of geometry;
b) from the standpoint of the documentation: the documentary sources allow us to formulate what we know about the buildings as bibliographic references;
c) finally, from the standpoint of location: a place and a given time are characterised by the presence of an architectural object (in this place), whose state is to be seen in relation to this given time.

It is clear that an architectural object, in the broadest sense of the word, is indeed the central link allowing us to attach references to evolutionary models, in other words, a natural mediator between the information to be manipulated. The representation can thus be understood as the morphological viewpoint on an architectural model[21] whose purpose is also to be used for the constitution of heritage databases.

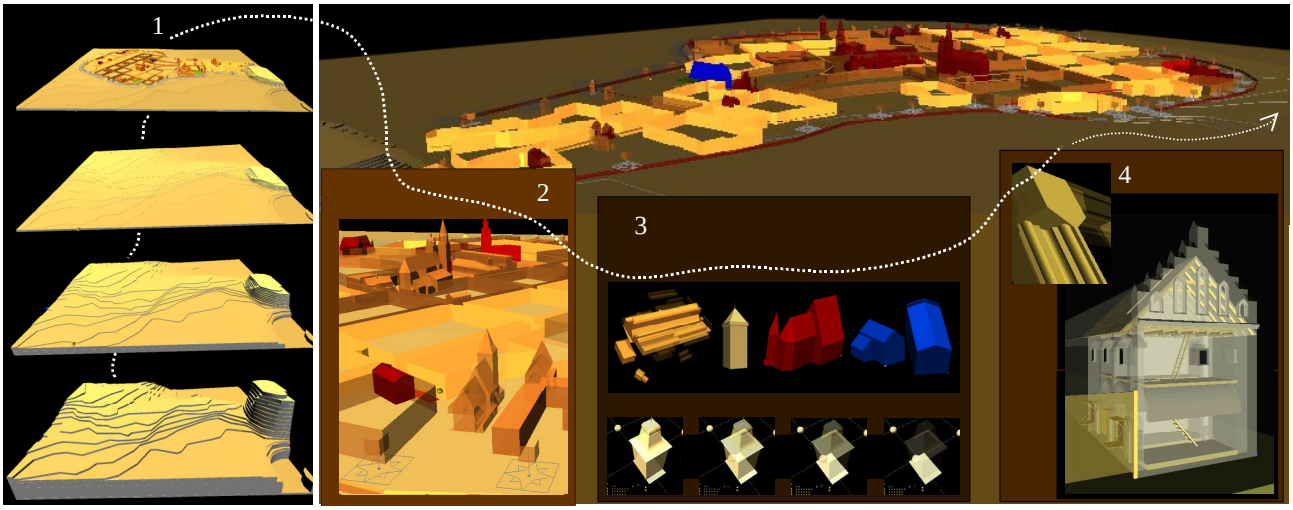

Fig. 7
The representation – tool for the visual evaluation of our knowledge– different scales for the old centre of Kraków.

However, creating such databases requires the information to be structured and stored, and the corresponding access tools to be implemented.
Two types of object are managed: architectural objects (VIA database) and documentary resources (SOL database). The morphology of the former is described in an XML file developed to produce dynamically 2D or 3D representations. The latter are described in the SOL base using standardised criteria (author, location, etc.).
The link between the artefacts and documents is made by the VIA database inside which we store data about each evolution of each

[21] *cf.* J.Y BLAISE, I.DUDEK, «*Règles d'identification et méthodes de visualisation d'objets architecturaux* », RNTI-E-2, From « Gestion de Connaissances » 2004

architectural object. This then enables links between the various developmental phases of a single architectural object to be formalised.Each evolution of an architectural or urban object has its own morphology, or a morphology “copied” from the previous or next phase (this information is then expressed by a semantic code inside the graphic representation).

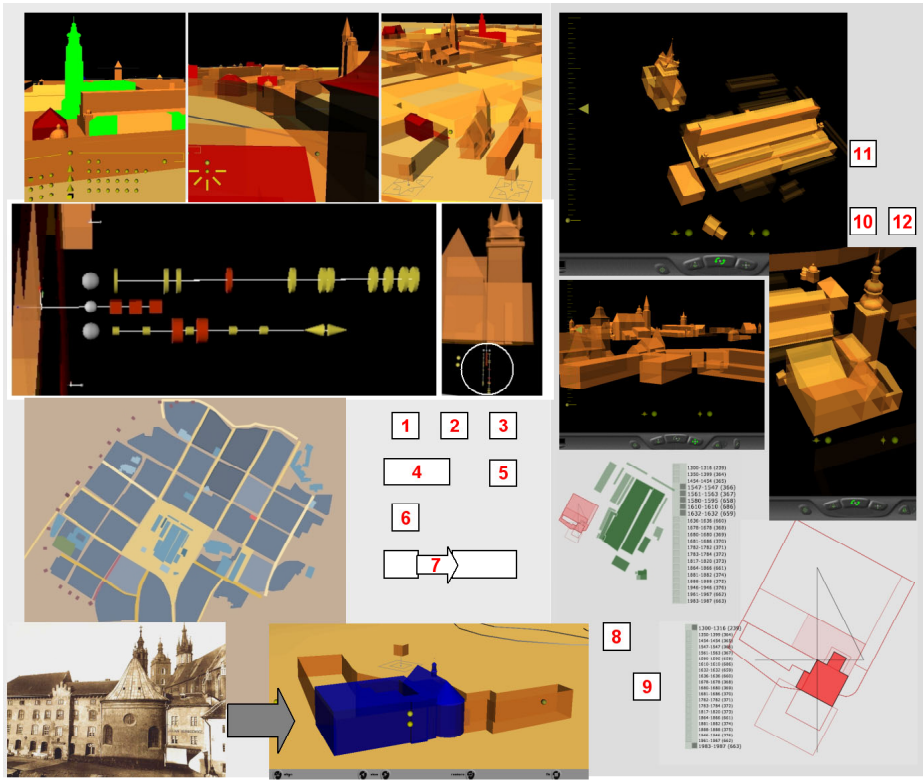

Fig. 8

Uses of alternative representations,

1, 2, 3 **-** 3D VRML models used as spatio-temporal browsing interfaces with codified representations to convey the information sets, display the interactive search tools for the scene (referral to the bibliography relating to the object, their typological entry, etc.)
4, 5 **-** 3D VRML themed models (open interactive indicators Form/Material/function)
6 **-** 2D (SVG) equivalent of the models
1, 2, 3, 7 **–** Shifting between documents and models: a means of repeatedly questioning the document. The dynamically constructed model reflects “what we know about this area in addition to this photograph” at the moment of inquiry.
8, 9, 10, 11, 12 **–** reconstructions of the building’s chronology with interactive selection of imprints on the ground per period of change (SVG scenes 8 and 9) and interactive time cursor in the 3D VRML scene (10 to 12).

For each evolution of artefacts, the VIA base includes a set of qualitative descriptors (*e.g.* alternative names that it may have had during the period studied). Among the more complex descriptors, we can cite the four indicators of dating, function, constructive typology and architectural typology, for which the values given to the object are accompanied by source-credibility-indications (using pre-determined grids). These grids indicate on what type of resource the given value is based (contemporary witness, later study with observations, simple hypothesis, etc.).Here is a “quantitative” idea of the work carried out in Kraków:

1. To date, the VIA database contains 817 records of evolutionary phases for 335 objects (*i.e.* an average of over two changes per object). This is of course an average; a complex building such as the former town hall is shown with 21 different evolutionary phases, while a number of urban blocks have remained unchanged (as “blocks”, which does not mean that buildings within the blocks have not changed). Each object is associated with a query to the SOL documentary database, thereby linking an object with its specific documentation.

2. Two thirds of the evolutionary phases thus described are represented by a specific morphology described in an independent XML file. For the remaining third, either we are unable to determine the form of the object, or the work has not yet been done. In that case, an object is represented by a form indicating that the data are missing. In parallel, some objects have been reconstructed without completing their documentary analysis, notably when they have a determining role in the town structure but their complexity makes documentary analysis lengthy. The proposed solution consists in indicating the missing information by a semantic code in the model.

3. The SOL documentary database contains 761 main documentary resources broken down for the most part into independent entries, as they almost systematically contain several types of data (maps, illustrations, texts, etc.) on several objects at several scales. It should be remembered that SOL does not store resources but describes them (author, date, etc.) and locates them (libraries, identification number, etc.). It is clear that it is not our role to manage archives directly, but simply to try and make them more accessible.

4. Since the representations are produced in response to users' queries, their number is not pre-determined. However, queries are provided by default on different criteria (object, object+location in relation to the object, date, etc.).

This work is based on a set of so-called "free" modelling languages, around the internet platform:

- OO programming language to represent concepts and implement content editing and consultation tools;
- generic CGI interfaces to process the user/system interaction via traditional Web browsers;
- RDBMS (mySql) interfaced on the Web;
- 3D and 2D representations based on standard ASCII languages, VRML and SVG;
- XML text sheets and post-processing by XSLT transformations.

The roots of the *informative modelling* approach are largely to be found in the complexity of the questions dealt with in this experiment: the work was primarily built around the idea of "information gaps" (uncertain, incomplete or contradictory data). As a consequence we had to develop dynamic graphics adapted to such pieces of data. Such graphics inherit the monosemic character of the sign from J. Bertin's works, the cognitive character of this sign from the tradition of architectural drawing[22], and the move *from narration to explanation* as described by E.R.Tufte.

[22] *cf.* J.C LEBAHAR, «*Le dessin d'architecte. Simulation graphique et réductiond'incertitude*», Parenthèses, *Marseille* 1983

Second example: 2D visual devices (SVG) for clarifying the morphological characteristic of a group of ancient theatres.

The main focus of this development is to try and implement 2D visual comparison mechanisms in order to analyse sets of information about antique theatres. We thereby expected to better understand and communicate the typology of the theatre. We also expected this development to give us through visual means a synthetic view of how the theatre typology evolved in time and space, around the Mediterranean basin, during the Greek and Roman periods. A diachronic approach, these comparisons should ultimately allow us to evaluate in a synthetic form what we know (composition and data on each theatre, synthesised in a visual signature; comparison of all theatres parameter by parameter) and also what we do not know (highlighting missing information).
The comparisons underline the following questions:

- what do we know about object **A** compared to what we know about **B**, **C** and **D**?
- from what we know about **B**, **C** and **D**, what can we deduce about object **A** (at the hypothetical level of course)?
- what can we learn about the evolution in time and space of the typological family [**A**,**B**,C,**D**] by observing for example that, compared to the general model of the classical theatre, **A** and **D** have an extra characteristic Φ and that **C** and **B** have an extra characteristic Σ.

A set of 36 classical theatres in four Mediterranean countries was chosen for this experiment. The proposed method can be described in three key steps:

1. A formal analysis of the typology to define the parameters and characteristics to be compared as well as the graphic sign used for the comparison. The result of this first phase is a univocal graphic sign symbolising the specific architectural composition of each theatre, as well as a database of relevant information.
2. A set of visual signs calculated dynamically for each theatre and displayed in an interactive “architectural” map showing the spatial distribution of the theatres.
3. A set of interactive tools within this “architectural” map, allowing the users to query the data base.

The results of this experiment illustrate what we mean by (and what can be gained from) informative modelling: an approach, a practice, whereby we can move from artefact representation to information visualisation. Moreover, this experiment provides convincing answers to a certain number of critical questions raised in the architectural heritage field:

- adaptation to a discontinuous knowledge acquisition process;
- adaptation to highly heterogeneous data, information and applications;

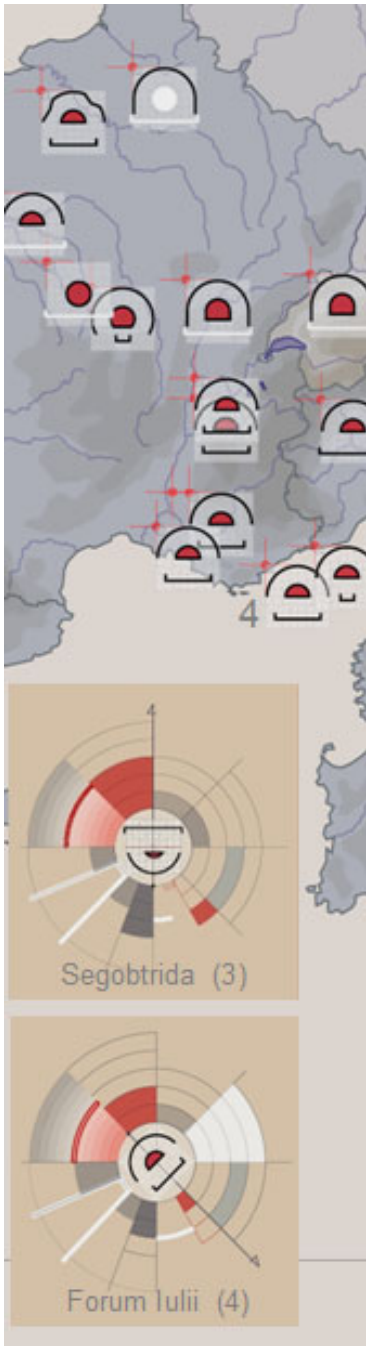

Fig. 9 Top: visual signatures of ancient theatres, a synthetic summary of the morphological characteristics of each theatre, distributed in space.
Bottom: an abstract visualisation of these same characteristics used for comparison in the set of cases.

- enhancement of visual comparisons – both on quantitative and qualitative information.

We believe this work demonstrates that, rather than reducing or simplifying the problem, the proposed methodological framework helps structuring and providing continuity to the analysis effort.

Conclusion

The informative modelling approach brings to light inter-disciplinary questions about representation, understood as an *investigative tool*, a tool for visualising objects *and* information. It provides a bridge between the domains of spatial modelling itself and of information visualisation. It is based on intersecting experiences and remains faithful to the specificity of the study of built heritage (uncertainties, heterogeneity of sources, etc.).
This approach has been established to meet a dual need:

- to make the architectural form a spatial and temporal filter through which layers of heterogeneous information can be brought together, such as measurement and documentation;
- to use digital models as iterative information visualisation tools, constructed and reconstructed from day to day as answers to questions, and aiming to be what the map is to the representation of territories.

We also see this methodological approach as a means of interdisciplinary questioning (*e.g.* Does the geometric modelling tool I use allow me to assess the uncertain nature of the information I'm handling? What are the links between the graphic output and documentary evidence?).
As such, this approach could raise doubts about prevailing technologies and methods which, disguised as solutions, are in fact sometimes part of the problem. In fact, it calls for a distinction to be made between the aim (What gain does it bring to the researcher? How reliable are the results over time? What knowledge has been produced and shared?) and the means (which tools, which formalisms, what resulting dependencies).

Formalised by a set of rules acting as a self-assessment grid, the informative modelling approach is perhaps a means of expressing questions which go beyond the single field of application that we wished to discuss. By bringing the issue up for discussion and repeated experimentation[23], we hope to go one step further in identifying this approach, in order to lay a solid theoretical and practical foundation for it, to identify the rules and limits, to judge what it can bring in terms of production and knowledge sharing, and finally to evaluate its scope at the different levels at which the built area is read and then understood.

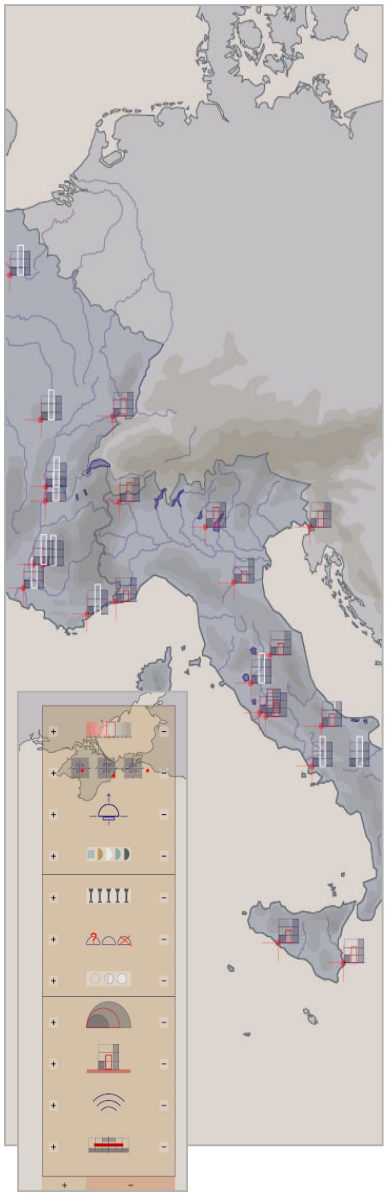

Fig. 10
Distribution in the space considered as a symbol of comparison of the theatres criterion by criterion (here, height of the *scenae*) compared to the extreme values of the collection studied. Bottom, left, list of interactive tools criterion by criterion.

[23] *cf.* the MIA Thematic School <*http://www.map.archi.fr/mia*>, the on-line Journal which follows it
<*http://www.map.archi.fr/mia/journal*> ***and*** <*www.ia.arch.ethz.ch/summit.htm*>