Spatial distribution and visual analysis of architectural semantic features

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Abstract: When facing partial evidence on how architectural objects evolved through time (often due to uncompleted information), it is important to provide the researcher with tools for a cross-examination of cases that may help him better delineate possible values for lacking information. In the case of architecture, we deal with data that can be attached to a given location (distribution in time and space) and to a given generic typology. This opens an opportunity to use pseudo cartographic representations in order to visually distribute objects that share a common typology. Unlike with geographical maps, we should however include visual signs that tell the user about the architectural composition of each object in the data set, as well as about its level of documentation. In this paper we try to demonstrate, using a data set concerning antique theatres, that visual comparative evaluations of the data can provide a major methodological breakthrough for cross-examination of information on architectural objects.

Key Words: Architectural heritage, Knowledge management, Interfaces, Information visualisation, Spatio-temporal data
Categories: H.3.3, H.5.2, J.5

1- Introduction and objectives

When trying to understand how edifices evolved through time, researchers analyse various pieces of data or information that help connect the edifice with endogenous facts (what happened to this edifice at time t) or exogenous facts (what happened at the same period elsewhere, what cultural trends the edifice reflects, etc.). At the end of the day, researchers expect to have gathered enough elements, enough evidence to state for instance how a particular building evolved through time, or to which other edifice this building can be compared to, etc.

But in the field of the architectural heritage, pieces of data or information notoriously vary in type, relevance and precision. Therefore sources provide indirect indications, most often uncertain, and this very uncertainty is the heart of a researcher's concern. As an answer, we have introduced in [Dudek, 05] a knowledge acquisition process that may let researchers state: "something existed at position π_1 between dates δ_1 and δ_2" and reference it by a formalism around which they can organise findings. Information about an architectural object can then be progressively delineated throughout an integrated investigation process. This process should let the researcher gather partial evidence on an architectural object on two different levels: evidence identified from the data on the architectural object, evidence identified on the architectural object itself.

However this "endogenous investigation" of the architectural object is only a first step in its understanding. Comparisons should then be carried out that will help understand an object with regards to objects belonging to the same typological family,

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but located elsewhere in time (“defensive systems at medieval period vs defensive systems at baroque period”) or space (“gothic churches in Spain vs those in Germany”). Comparisons should underline three questions:

- What do we know about an object **A**, in comparison to what we know about objects **B, C** and **D**?
- From what we know on **B**,**C** and **D**, can we deduce something about object **A** (at hypothesis level) ?
- What can we learn about the spatio-temporal evolution of the [**A**,**B**,**C**,**D**] typological family by observing that for instance **A** and **D** have additional feature **φ** when **C** and **B** have additional feature ζ ?

Our research’s objective is to develop a set of visual tools, including spatial distribution representation, that provide the following services:

- Help gaining insight on each object and on the data set as a whole by fostering one-to-one or several-to-several comparisons (of features).
- Help characterising each object by providing a univocal “visual signature” not of the object itself but of the information behind the object.

A collection of 36 antique theatres, distributed across four Mediterranean countries, has been chosen as experimental data set (this point is discussed later). In this experiment, the “antique theatre” typological family can be understood as what J.Bertin calls the invariant of a graphic, and locations and features of each antique theatre inside the data set play the role of “elements of variation”. The method we introduce identifies three key elements:

- A formal analysis of the architectural typology in order to define the parameters we need to compare, and the visual sign in charge of conveying comparisons. Result of this first step is a univocal graphic symbolisation of the typology’s architectural composition (see Fig.1.), and a relational database containing the data set itself.
- A set of visual signs, calculated dynamically for each object in the data set, and displayed inside an interactive “architectural map”, support for the spatial distribution of objects.
- A set of interactive tools, nested inside the “architectural map”, that will let the user query the data set on comparisons. (For instance, comparing a feature of the typology such as dates of construction) or on a given object (visual signature, including information all the features of the typology for the given object) (see Fig.1.).

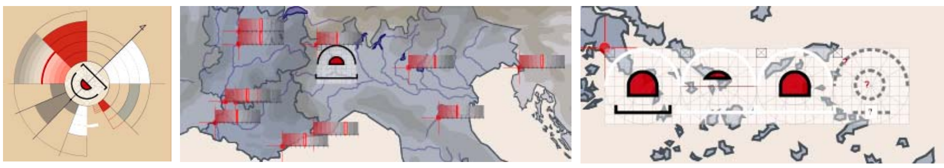

Figure 1: Left, “visual signature” of a theatre (case of Aosta- Augusta Praetoria Salassorum) – Center, spatial distribution of data set (partial) with a timeline bar for each theatre showing its dates of construction. Right, variation of typology and of information level (white - lacking information, dotted lines, morphology not known).

It has to be stressed that this paper focuses on the method and implementation. Since our data set is partial, no conclusion should be expected on antique theatres in general, but only on possible benefits of developing graphic disposals as "*knowledge and discovery tools*" [Bertin, 98]. In the following sections, we present the research in its context (background and related works), then we furnish the details on the method and implementation, to conclude finally with observations and perspectives.

2- Research background

Thirst for details, ambition to resemble reality have been at the heart of architectural representations since the renaissance and Brunelleschi's *drawing in perspective* experience [Fanelli, 80]. In contrast, abstraction is the core feature of graphics in the field of information visualisation, even when metaphoric figures are used. We have in recent research work raised the following issue: can something exist in between those two graphic practices, and if so what can we gain from their integration?

As an answer, we have shown, in line with works like [Alkhoven, 93] that the complexity of "real" architecture can be reduced to a metaphorised, typological representation. Not only do we then gain abstraction, and therefore compatibility with *infovis* methods, but we boost the flexibility of the data acquisition process (allowing a well-documented object to be represented in the same visual disposal that a poorly-documented object, only with a graphic codification that shows this difference).
Graphics in our field of application are still today either an end-point to the knowledge acquisition process (virtual reconstruction for instance) or a side-effect of this process (2D maps of archaeological findings for instance). We think, basing on experiences like, that it is possible to develop a different practice and re-invest representation as an *exploratory tool* as [Rod, 00] puts it. We have introduced in [Dudek, 06] elements of definition of this new practice, that we call ***informative modelling***.

Informative modelling is about putting the data first, when many graphics in our field of application are thought for seduction first, and consequently provide an inauthentic visual result from which no insight can be gained on the edifices or on our understanding of the edifices. In this paper we introduce a new evaluation of the informative modelling methodological framework, focused this time on the combination of three constraints: a non-homogeneous typological family (antique theatres ranging from Greek to Gallo-Roman period), a spatial distribution at geographical scale, and a necessity to provide comparisons inside the data set.

3- Related works

The recent trend of "realistic" VR models such as [Perkins, 03] finds a root in the history of architectural representation, as previously mentioned. But analysts of architecture during the XIXth century used to manipulate various representation modes, some of which quite alike what we propose, at least conceptually. One can observe that spatial distribution of information also has a history in the field of architecture.

In the field of information visualisation, graphics naturally have features closer to Bertin's view ("…*a graphic is never an end in itself: it is a moment in, the process of decision making…*") than to VR trendy stuff. But in that field a barrier remains for us:

the graphic sign that bears the information usually has nothing to do with the information itself. It acts as a substitute fostering the readability and the navigability of the data, like in [Andrews, 03]. Even when architectural metaphors are used, like in [Russo Dos Santos, 01], the data reduces architecture to either a stage decoration, or to a mental image [Spence, 01]. Other solutions have been investigated by for instance [Ioannidis, 02] where pieces of architecture in 2D or 3D help interrogate a database. But in those cases abstraction, and therefore this effort of reduction of complexity at the heart of a gain of readability, is absent. Still, convincing hybrid solutions have (rarely) been proposed, notably by [Alkhoven, 93] on the city of Heusden, or more recently by [De Luca, 05] on smaller scale architectural objects. These experiences show that abstraction and figuration can be integrated as alternative/mixable modes of representation of our knowledge, a statement at the origin of informative modelling.

4- Data set and method

The data set we have chosen is an ensemble of 36 antique theatres ranging geographically from Greece to Spain, and in time from circa 448 BC to 200 AD (dates of construction). Theatres, a typical element of Antique towns, have common features wherever they are, and whenever they were built: their architectural composition (three major structures: the *cavea* and its rows of seat, the *orchestra*, and the *scenae* with a vertical sub-structure, the *frons scenae*, behind it, see Fig.2). But elements of variation in the theatre typological family are numerous (for instance, scenea built on masonry in roman theatres, cut in natural slopes in Greek theatres), and we will not here discuss each of them.

Still it is important to stress that if we are to enable visual comparisons (and thereby maybe better understand the variations), we need to clearly delineate for each structure its specific parameters. Naturally, parameters exist, such as date of construction, which qualify the theatre as a whole. The specificity of our approach appears to us rather in the fact that "inside" the theatre we identify significant architectural structures that we analyse formally in step 1 of the proposed method.

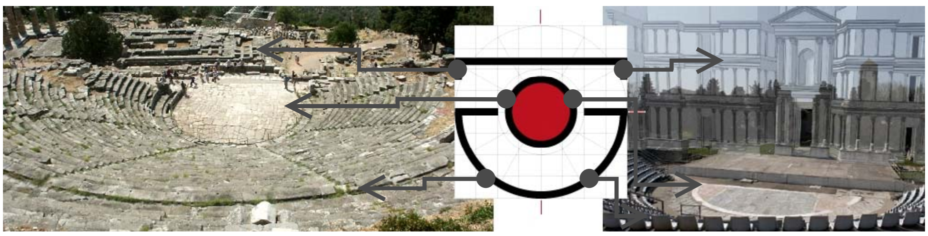

Figure 2: Three main structure of an antique theatre (left, cavea and orchestra in Delfi, right, a simulation of the scenae in Arelate.

Step 1: formal analysis: Formal analysis of the architectural typology can be described as an investigative process in which we first identify main structures (*cavea*, *orchestra*, ...) and then for each of them analyse elements of variation of the structure across the data set. In Fig.3 we give an example of this process in the case of the orchestra. At the end of this process we have defined the parameters we need to compare (and thereby the DataBase structure), as well as the visual sign in charge of conveying comparisons. It has to be said that because we are dealing with transformed when not totally destroyed objects, a part of the input we get is only qualitative ("the orchestra was semi circular but we have no idea about its actual radius"), and another part of the input is simply lacking. Therefore the visual sign is not only in charge of transmitting information, but also in charge of keeping it at the proper abstraction level, and includes a codification for "absent" data.

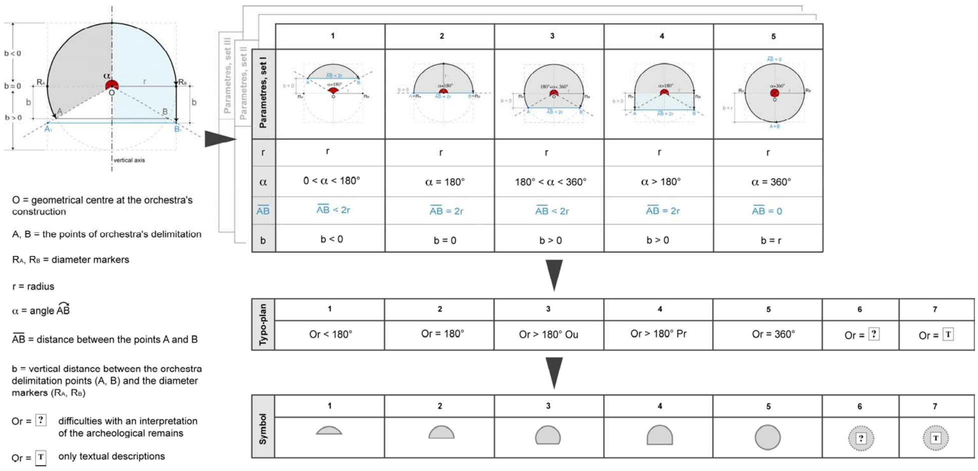

Figure 3: Illustrated on the case of the orchestra, parameters of the physical object are converted into typological indications, and finally into visual signs.

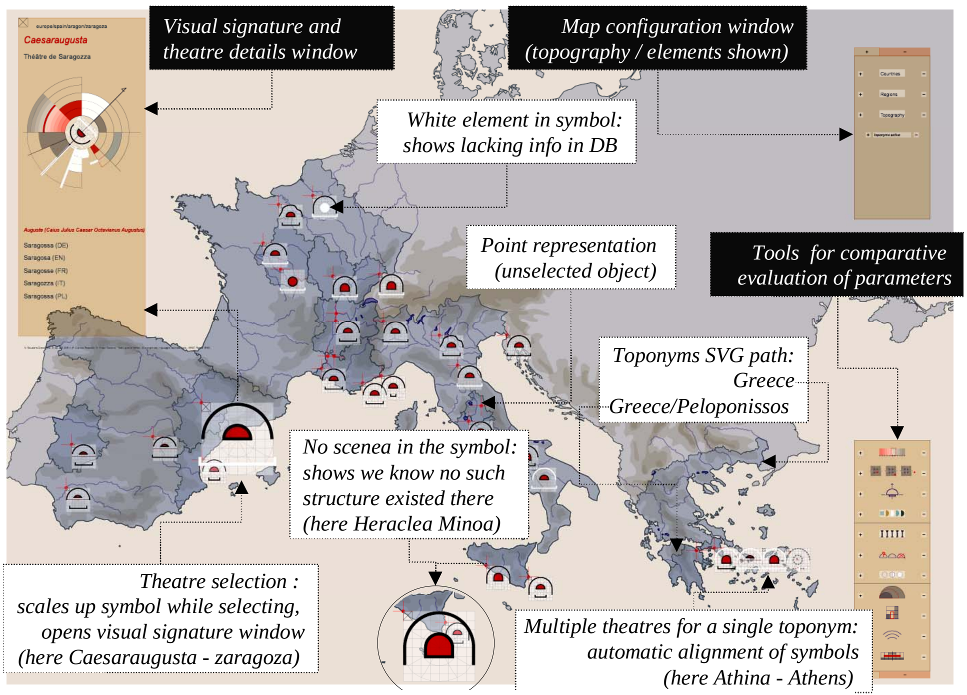

Figure 4 : Main elements and features of the SVG interface.

Step 2: Spatial distribution. As a result of the previous step, for each object in the data set, a visual sign that identifies the object's typology can be produced dynamically from the database. The positioning of this sign inside a pseudo cartographic representation is then required in order to distribute the signs. This is done through the toponymy of the object (see [Dudek,05]) thanks to which each object is marked as belonging to a toponimical hierarchy (ex. europe/italy/valledAosta/aosta/…). At each level of this hierarchy an SVG path can be produced, enabling the positioning of the object inside an interactive "architectural map", where the user can switch from a point- representation of the theatre to a visual representation of the theatre.

Point selection prompts the switch to sign representation, and sign representation prompts the display of the theatre's visual signature details (translation of the toponym including in Latin, name of emperor at the time, etc.). Interactive configuration of the "architectural map" allows users to add/retrieve elements of topography/geography (see Fig.4).

Step 3: Visual tools. Up to here what we have done is distribute in space a visual sign that connects each theatre to a given implementation of the antique theatre typological family. The last step is then to use the parameters defined in step 1 in order to enable fine-tuned comparisons. Two possibilities are given:

- Showing, on the map, the value of a given parameter for each object (for instance radius of orchestra (see Fig 5).
- Showing, through the "visual signature" of a theatre, the combination of values for parameters of a given theatre (see Fig 6).

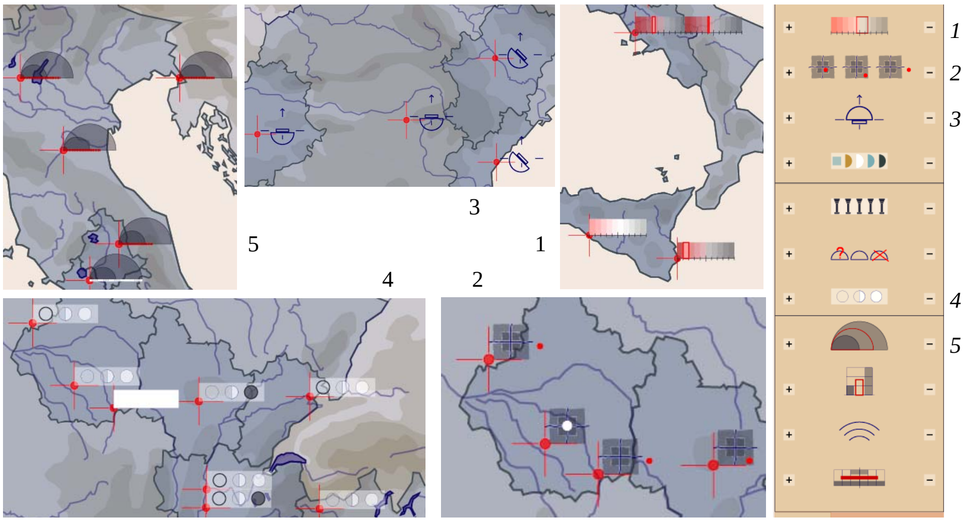

Figure 5 : Value of the same parameter across the data set, examples: 1 – dates of construction, 2 – urban position, 3 – orientation, 4- type of transformations, 5 – diameter of the cavea (relative to the min and max inside of the data set).

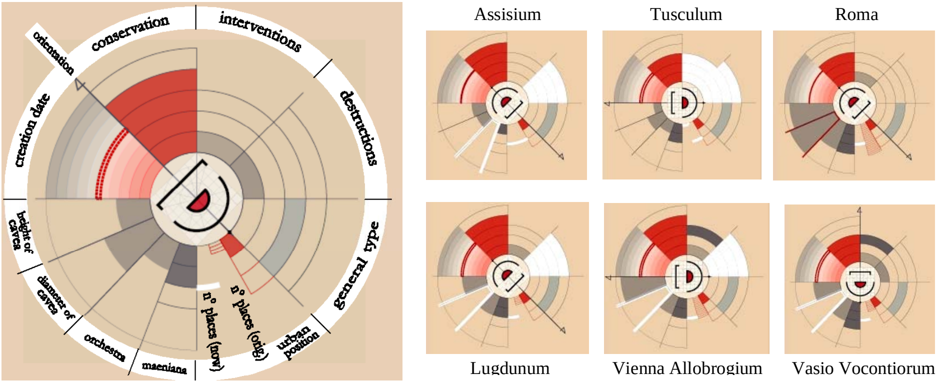

Figure 6: Left, visual signature of a theatre, (Tergeste, known today as Trieste). Right, a comparison of six theatres with the same structure (identical configuration of cavea, orchestra and scenae – indicated by an icon in the middle).
Note similarities (period of construction, general type, urban position,…) and differences (orientation, conservation, …). White colour indicates that an information under consideration is missing.

5- Implementation

The implementation of the method is based on a combination of standards or robust technologies, and can be considered as quite straightforward. Graphics are SVG inside which interactions are simple Javascript commands. The SVG files and their Javascript associated scripts (initialisation and/or commands) are produced at query time by a set of Perl script that read the RDBMS (MySql) inside which the data set is maintained. The toponymy (and therefore the pseudo-cartographic representations) is handled in a slightly more complex way, based on an XML/XSLT set of documents produced thanks to a hierarchy of Perl classes [Dudek, 05], and exploiting the recent development of SVG technologies [Keller, 02].

6- Limitations & Perspectives

Two benefits of the method we introduce can already be underlined:

- Because it includes a formal analysis step not centred on quantitative evaluation alone, comparisons inside a typological family are made easier, including those between objects on which we have a very different "quality" of information (some well known, some poorly).
- Because what we convey in the graphics is the information on objects, filtered by an architectural analysis, the graphics does not only enable comparisons but also underlines lacks of information, showing us unambiguously what we know and what we don't know.

But at this stage we have only implemented mono-parameter comparisons and provided a global visual signature. An obvious perspective for us will be to provide solutions in between, such as comparing the variation of two parameters (for instance, seat capacity in relation with location or with time). It has to be stressed that the graphics we have produced, and the tools associated with them, are a direct result of an analysis of the architectural composition of antique theatres. Because an effort was made on finding out semantic features of these edifices, graphic disposals do prove useful. In other words, it is because the basic data on theatres has been filtered in order to match an architectural analysis that graphics become meaningful. Consequently, it is important to note that the method we propose is not a generic visualisation method one could apply to whatsoever. It is basically a knowledge-driven method, an effort *to document, preserve and reason about that knowledge* in the words of E.R Tufte [Tufte, 01].

More generally, this work, although a lot more needs to be done, does already underline the gain of insight researchers in the field of the architectural heritage, can expect from investing in "graphics that say something". There is no doubt our contribution remains very isolated in the above mentioned application field, but the results we have achieved show it is worth trying to exploit architectural analysis using concepts stemming from *infovis*. In that sense, this contribution can be seen as underlining once more a statement of need: develop *informative modelling* as a methodological framework.

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