

Identifying and visualizing universal features for architectural mouldings.

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Abstract: When observing architectural mouldings with an amateur's eye, they do seem to have something in common – or at least comparable features. But what, precisely? Curves? Alternation of curves? Rhythms and proportions? This contribution introduces a concept that aggregates abstract features of a 3D moulded object, may the object be real (existing or having existed) or purely theoretical (from literature). Our research – at the intersection of architectural modelling and of information visualisation, investigates how new metrics, along with a cognition-amplifying visual encoding, could help uncover patterns and exceptions in the design of mouldings (across historical periods, across territories, across stylistic affiliations, across families of 3D objects, and across sources) and ultimately could help gaining insight on relations of mouldings to one another, and to the architectural theory.

Keywords: knowledge visualization, information visualization, patterns, heritage architecture, comparative reading.

I. Introduction

If we are to portray what architectural mouldings have in common, we need to think out a universal observation ground, enabling visual comparisons of moulded objects, and linking instances to theory. When looking at existing solutions, it appears that many solutions have been introduced in recent years that help handling and interfacing heterogeneous data or archival documentation [1], promote spatial information management systems [2] or facilitate the acquisition and representation of metric data [3] and understand its impacts in the field of the cultural heritage [4] [5].

Yet one of the methodological issues still unsolved is how these progresses can improve, or at least question, existing theoretical frameworks. And one of the most stable of these frameworks is the description of mouldings, a very classic piece of knowledge in history of architecture.

Our contribution investigates how traditional analyses of historical architecture can be complemented with new metrics, and new visual solutions enabling better comparative reading of mouldings and of their components, and better

cross-examination of poorly-supported parameters such as rhythms and proportions. It is quite easy to spot a number of differences between moulded objects (Fig. 1).

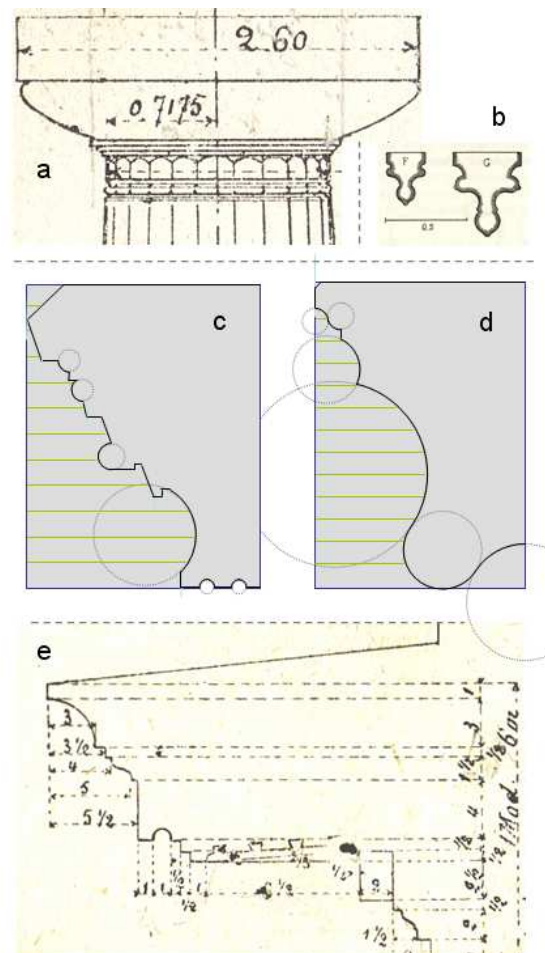


Figure 1. Evidence of differences in size (a,b); in rhythm, proportion, shapes (c,d), in use as a member of construction (a-b-c-d, e), in the documentation's content (a,e - note that in a real size is known whereas in e only proportions of elements to a common reference known as "modulus" are given). (a,e) [6], (b) [7], c, d survey by author.

Intuitively it is also rather obvious that, never mind the style, the historical period, the underlying 3D object, moulded objects have something in common. But will it be as easy to *present the evidence* that there are common features?

Broadly speaking, the architectural theory identifies on one hand individual components (Fig. 2a) – such as ovolos, cavettos, etc. – and on the other hand canonical combinations (Fig. 2b), often considering the latter as time markers (Fig. 2c). *Can we, if adopting a thinner grid of parameters, observe and measure other tendencies, such as geographical patterns, evolution of a style in time?*

Basing on components and canonical combinations, the architectural theory privileges rhetoric comparisons and reasoning.

Can we underline patterns and exceptions by introducing more objective metrics?

Finally, writings about architecture mention profiles in the context of 3D objects. They thereby, de facto, deny or ignore similarities between profiles of different 3D objects – let's say for instance arches, cornices, capitals, beams.

Would it be possible to think out an analysis grid that could transfer profiles of different 3D objects into a unique visual encoding?

As an answer, our contribution underlines the necessity and benefits of introducing a level of abstraction in the analysis so as to order to portray - beyond the physical components of mouldings - rhythms, proportions, design.

The approach is intended at confirming or uncovering patterns across styles, across geographical areas, across cultures, objects and building materials. Its purpose is in a first phase to serve as a new analysis grid for research and pedagogy, and on the long run to facilitate a semantics-enabled post-processing of survey results.

II. Research context

A. Describing and representing mouldings

Mouldings are a fundamental part of the architectural theory, mentioned since the first known treaty of architecture by Roman architect Vitruvius, intensively used in historic architecture [8], [9], and still present in nowadays catalogues of ornamental components [10]. However defining what they are is not that easy.

Cyril M Harris [11] defines them as “*a member of construction [...] so treated as to introduce varieties of outline or contour in edges or surfaces, whether on projection or cavities [...]*”. His definition is clear, but is it operational, directly transferable into objective metrics? We need to interpret such qualitative definitions in order to identify non-ambiguous, operational concepts.

Accordingly, we propose to distinguish three notions, encompassing different spatial granularities:

- Individual components “*on projection or cavities*” (Fig. 2a), with alternating edges and surfaces (according to [11] components are generally divided into three categories - rectilinear, curved, and composite-curved). These components are usually identified as elements of decoration, and consequently present in dictionaries of art terms as well as in the architectural theory. What is

important to note is that they are thought of as being *2D elements*- with varying extrusion modes possible.

- A profile consisting of “*varieties of outline or contour*” (Fig. 2b). Profiles too are thought of as 2D elements. Bases or capitals in Greek, Roman or Classical architecture are 3D objects naturally, but their canonical description as can be found in literature is a section.
- An underlying 3D object (“*member of construction*” (Fig. 2c), this time designed in 3D as an element of architecture – arch, pillar, lintel. The profile of a 3D object, carved or coated, may cover only a portion of the 3D object, and in all cases is extruded according to the 3D object's specific geometry (linear, multi-linear, circular, etc.).

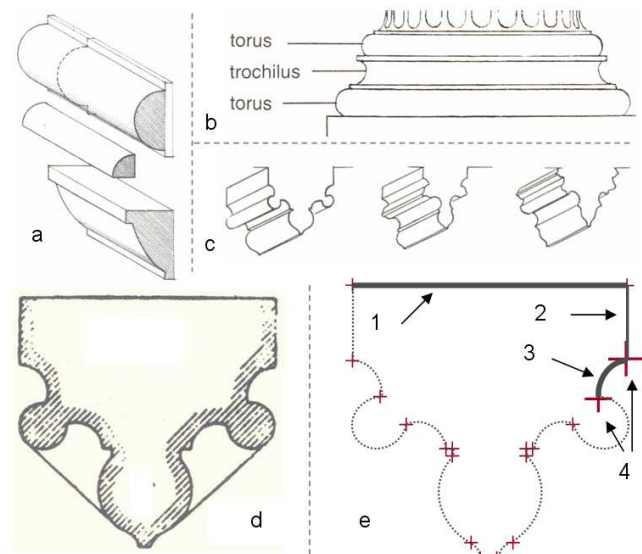


Figure 2. In (a,b,c) An illustration of the three notions needed to disambiguate the word “moulding” - **a**) individual components – here half round, quarter round, ovolo, [10]; **b**) The profile of a canonical attick base – combination of individual components, [12]; **c**) underlying 3D objects extruding profiles (here arches) with 3 combinations representing steps in the gothic trend's evolution [12].

In (d,e) decomposition of a profile into segments - **d**) Profile of a gothic arch [13] – **e**) segments of a profile classified as : contact surface (1), unmodelled (2) or modelled (3), segments between control points located on vertices (4).

Methods and tools available to study and compare mouldings remain mainly qualitative (Choisy [13] describes profiles with expressions like “flabby and heavy aspect”, “ending up in complication and baldness”).

Let us here take an example of where such arguments lead authors. Hypotheses are put forward that link mouldings, style and time slot:

- To a given stylistic affiliation (corresponding most often to a given period in history) corresponds a given composition of profiles [14]. A well-known example is the succession in time of the Dorick, Ionick, and Corinthian orders in the architecture of ancient Greece. Within these three “families”, sub-groups are then identified that further narrow the time slots – with words like “archaic” or “classical” more than with precise dates, in fact.

- Within a given stylistic affiliation changes in proportion or in number (more than in the actual language, i.e. in the type of components) correspond to successive time slots in the evolution of the style. For instance, Choisy's [13] description of bases of the Gothic order from the 12th to the 15th century focuses on changes in proportions of a scotia and two torus. Wilfried Koch's analysis of the evolution of gothic pillars (Fig. 3) [12] illustrates the plus and minuses of such qualitative classification efforts, with division lines hard to define, and an argumentation the reader has to guess for himself.

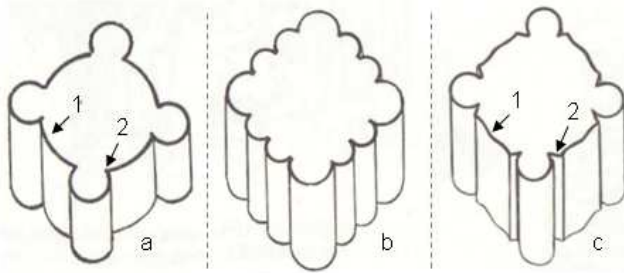


Figure 3. Evolution of the Gothic Pillars, according to [12] - a) early Gothic; b) Classical Gothic; c) late Gothic. Division lines and argumentation remain unsaid. Compare here profiles a) and c) i.e. the most distant in time. Where is the meaningful difference, the difference one could weigh? Circular vs. square section? Longest surface rounded vs. flat (1)? Vertices vs. fillets (2)?

So what methods and tools are today available in order to observe – on the basis of objective factors – such a semantic dependency? The architectural theory itself is of poor support – its aim being most often normative more than analytical. We need to point out relevant variables, which can to be cross-examined in order to gain some understanding of similarities, patterns, exceptions. To do this, we shall step out of architecture as a discipline. From Bertin's *graphic semiology* [15] to Tufte's *visual explanations* [16], a number of fundamental references can help us understand where to go next: introduce an abstraction level to bridge the gap between the architect's traditional figurative representation, and knowledge / information visualisation basics [17].

In [7] we discussed why researchers in the field of the architectural heritage now need to view computer-based imaging as more than mere communication. We tried to lay the basis of an *informative modelling* methodology in which the representation of artefacts does not claim veracity, but supports dynamic information retrieval and visualisation, with some possible applications presented in [18] [19] [20].

In this contribution focus will be put on the “acquisition of insight into abstract data” [21] – in the sense that we will perceive a 3D object as a set of abstract variables. In his pioneering research on wooden ceilings in Poland, Jan Tajchman [22] introduces the idea that counting a profile's concave / convex curves can act as a parameter in a classification effort (combined with dating, geographical location, and typology indicators). In his approach the size and angular range of curves are ignored: only the rhythm created by the alternation of concave / convex curves all along

the profile acts as a division line in the classification effort (Fig. 4). In that sense, Jan Tajchman already introduced this abstraction level we believe is needed.

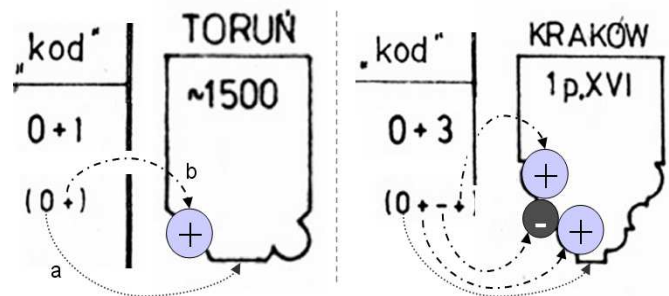


Figure 4. Profiles for Group 0 (codes 0+1 and 0+3) of Jan Tajchman's classification. As can be seen 0 refers to profiles with a flat bottom component (dotted line a on the left example), and concavity is counted in a binary +/- mode (dash-dot line b on the left example). Only “noble” components (i.e. parts that are actually carved) are taken into consideration. (Drawn over Jan Tajchman's original graphics).

Yet his method applies to wooden ceilings only, and intervenes solely as a mean to classify items (into groups of items that “have the same number and alternation of concave and convex curves”). It does not allow comparative readings within a group. His description does integrate an abstraction level, but his graphics are hand-produced, figurative. His vision is at the root of our research, but we expect to extend it by introducing other constraints:

- identification, labelling and reading of proportions of each segment, with support for angular ranges;
- inclusion in the list of segments not only of the “noble” components that make up the moulding, but also of the segments that are in contact with other objects, or of those that remain unmoulded;
- a unique model for various types of 3D objects;
- qualitative markers (ex. stylistic affiliation, material);
- a visual encoding effort and its implementation as dynamic web-enabled representations (2D SVG graphics produced on the fly as results of query on the set of items).

B. Contemporary works on the topic

Jan Tajchman's contribution differs from mainstream research works on heritage surveying and analysis by the fact that he identifies the semantics behind the geometry of a 3D object's profile. Although not supported by computer-based formalisms or solutions, his approach remains a leading-edge one in its ability to foster cognition.

By contrast, mainstream works have for more than a decade strongly focused on how to apply survey techniques and tools to architecture – to architecture seen as surfaces in a 3D space, architecture seen as primitives and meshes, should we add. Photogrammetry, videogrammetry, photo-modelling, laser scanning techniques (and combinations of the above mentioned) have been tested on moulded elements of architecture, and sometimes with convincing results as far as geometrical exactness is concerned. But at the end of the day these contributions provide valuable information on how to

capture a profile's geometry, not on how to capture its semantics. This issue has been raised in works like [23], [24], but it remains today a hot research topic. Applied to architecture, the issue is raised from the spatial sciences side for instance by [25] who introduces a 3D building simplification algorithm capitalizing on symmetric elements to highlight what the authors consider as geometric specificities of building architecture “such as right angles”. This time from the computer graphics side, [26] proposes a formal representation of consistency constraints (dedicated to building interiors) used in modeling operations in the context of lighting and radio-wave propagation simulations. And indeed a great number of contributions stemming either from the remote sensing community or from the computer graphics community are focusing on geometrical simplification (see [27] for recent more general Computer Graphics and Geometric Modeling contributions). But simplification as we need it is not be about diminishing the number of faces or vertices of 3D objects, it is about reducing 3D objects to a set of features that could be used to foster comparisons. In other words, it is about applying John Maeda's first law of simplicity: reduce (“the simplest way to achieve simplicity is through thoughtful reduction”) [28]. Let us exemplify this point: when trying to draw the map of a forest (may you be a cartographer or J.R.R Tolkien), do you count trees and draw one tree out of three – or do you replace trees by some symbolic representation adequate to the goal of your map? Reduction is at the heart of cartography, as demonstrated by J.K Rød [29]. But beyond cartographic practices, Michael Friendly [30] shows that it also is a fundamental concept of data visualization. Our position [31], is that when you don't know what you are looking for, the best survey technique may end up being useless. And therefore we consider a first step should be finding out what are the meaningful features to observe in order to gain some understanding about a profile's position in the history of architecture. Naturally, we shall not pretend having solved in general terms the survey post-processing issue. We only intend to show, on real cases, the possible benefits / limits one may expect if turning the question the other way round: identify elements needed to understand the object first, and then think about surveying – or even forget about it if unnecessary.

III. Objective, method, constraints

A. The humanities perspective: acquiring heterogeneous, inconsistent data sets.

Our objective is to provide researchers with metrics and graphics for mouldings analyses, allowing more efficient and more objective descriptions, comparisons and classifications, and applied across varieties of 3D objects.

It is important to mention that inputs may strongly vary, since we may need to compare here an existing 3D object from which we extract a contour, to there a purely theoretical profile known to us only by a 2D cross section represented in an old printed treaty (Fig. 5). Furthermore, precision of the input also varies. On one hand, theoretical analyses are often backed up by 2D, hand-produced graphics (that may be dimensioned or not) with varying accuracies. Inside the short bibliography we

propose, [6],[7],[22] draw accurate and precise figures, but writers focusing on typological reasoning like [11] or [12] may not do so. On the other hand, the quality of the data extracted from 3D surveys depends on the actual physical conservation of the object (and quite often vertices are eroded or worse).

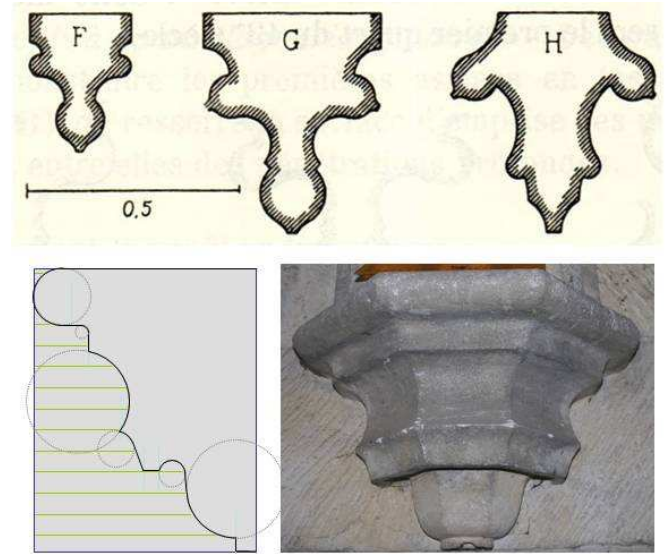


Figure 5. Heterogeneity of sources: top, three arches that [7] classifies as late gothic, without mentioning to which edifice they belong. Bottom, profile of an undocumented, undated corbel of the gothic cloister in Saint-Maximin's basilica, extracted from our 3D survey in 2010 (photomodelling).

Accordingly our objective - a methodological framework – corresponds to three distinct research issues: data acquisition procedures, knowledge modelling, and visual encoding. In this paper we focus on steps 2 and 3 – we have shown in previous contributions that acquisition techniques do exist that could provide correctly formatted inputs to steps 2 and 3 [31].

B. The knowledge modeling issue

Our modelling bias can be summed up as follows: *and what if, instead of having 3D objects, we could align on a straight, 2D line each of the object's components (Fig.6)? We could then compare objects to one another, components to one another, analyse rhythms, ratios, composition, proportions and reuse the same analysis grid across various 3D objects.*

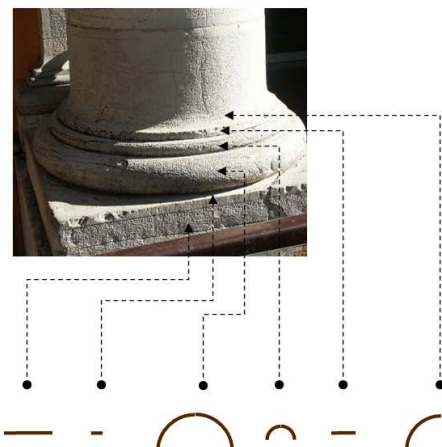


Figure 6. The modelling bias – identifying components, aligning them so as to enhance comparisons.

In order to do so, we transfer the somehow ambiguous notion of “mouldings” (supposedly 3D, but mostly represented in literature by a 2D cross-section, its only normative aspect) into a concept called MetaProfile, described by:

- a list of segments (themselves concepts described by various attributes, detailed hereafter) – segments mean here both the moulded and the unmoulded parts;
- a time slot (with certainty qualification, so as to handle cases when the indication we have is for instance “middle of the XVth century”);
- a geographical position (represented as an item in a hierarchy of toponyms - ill-localised pieces of architecture are represented by a “containing” toponym that can be a city, a territory, a region, etc.);
- geometric inputs (optional, allows handling of the object in 3D);
- sources, i.e. either the piece of literature we take the profile from, or how and when the data was acquired if we did the observation ourselves;
- elements of architectural semantics (ex. stylistic affiliation, 3D-shape generation mode, symmetry, material, position of the underlying 3D object in the DIVA ontology [32]).

As can be seen, we define mouldings at an abstraction level where 3D data is optional. We *reduce* (in the sense of [33]) a moulded 3D object to its **cross section** and to **qualitative data** expressed either through lexical scales (ex. material, stylistic affiliation, sources used) or through specific data models (dates – a doublet of integers with a certainty marker; localisation – a toponym as developed in [5]).

The cross section itself is decomposed into a list of independent segments in between control points. Control points correspond in most cases to vertices of the 3D object – but with exceptions (called ligatures) when the object’s design includes a voluntary tangency between curves as often in the Gothic period (Fig. 7).

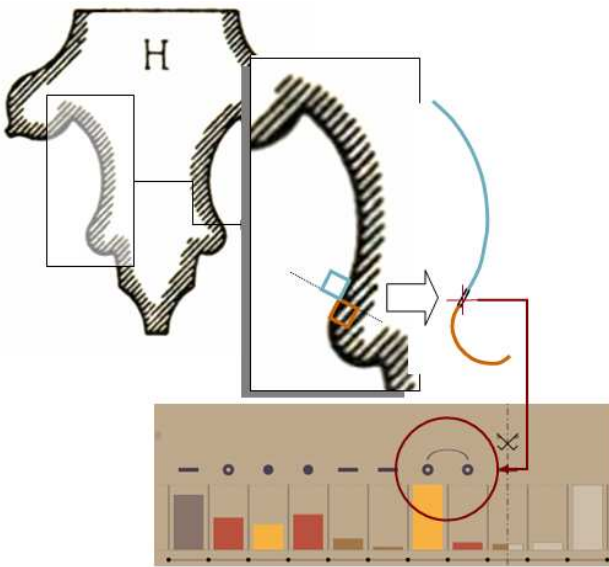


Figure 7. Control points most often correspond to vertices of the underlying 3D object, but there are sometimes more complex cases - voluntary tangencies between curves (here illustrated on an example from [7]). A specific marker is added to the description of the segment, and also used at visualisation time.

A segment – a nested object in the sense of Object Oriented Programming - is defined by a set of qualitative or quantitative attributes:

- curve type is represented by a closed lexical scale, it says whether the segment is moulded, visible but unmoulded, or hidden (contact surface);
- canonical name links the segment to a closed list of terms used in literature to identify mouldings (represented in the DIVA ontology [32] with definitions and translations in four languages);
- control points (Fig. 8b) mark the two ends of the segment, they are represented by two x,y points;
- concavity (Fig. 8c) re-interprets the three categories - rectilinear, curved, and composite-curved introduced by [11]. It is represented by a numerical scale, and is used to differentiate flat, convex, concave, and complex segments. A difference is made between canonical round curves (one centre, half-round or quarter-round) and non-canonical round curves (one centre, but angle covered different from 90 or 180). Table 1 illustrates values that the concavity attribute may take on various examples.

Segments can correspond to contact surfaces (Fig. 8c-5), visible but unmoulded surfaces (Fig. 8c-4), or may correspond to one of the profile’s main curves (Fig. 8c - 1, 2, 3) – individual canonical components as defined in the architectural theory. In all cases the geometric information stored inside a segment is limited to two control points. This implies that each component’s geometry will be known only in a purely qualitative manner – concavity, curve type and canonical name.

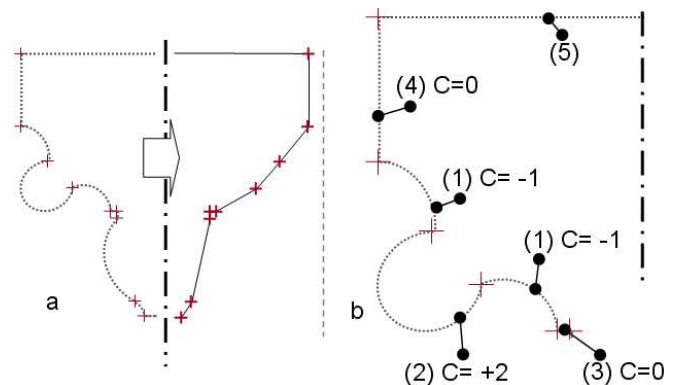


Figure 8. Identifying and qualifying segments of the profile: **a)** the profile is reduced to a list of control points and segments; **b)** a numerical scale called concavity is used to differentiate concave (-), convex (+), and flat curves, (0 - flat curve, 1 - canonical curve, 2 - non-canonical round curve, 3 for complex curve).

The segment’s length will correspond to the distance in 2D between control points – not to mix with the perimeter of the component. This choice, odd at first glance, is in fact a modelling bias that we hope to prove useful. Handling a thorough geometric definition of each component would in the context of this research pose two problems:

- a costly data acquisition procedure,
- an unfair view of ill-defined profiles (common when observing remains of edifices – measuring the perimeter of an eroded component would result in faulty data).

Furthermore, what is at stake here is not the exactness of a geometric model, but the usefulness of an interpretative model. We have therefore deliberately chosen to try and see what can be gained by reducing the description of a segment to two points and qualitative tags.

Table 1. Values of the qualitative attributes for the most basic components usually found inside profiles (un-exhaustive list, redrawn from examples by [10], [11], [13], terminology adapted from [10], [11]).

<i>Flat curves</i>	
	curve type: moulded canonical name : fillet concavity : 0
	curve type: moulded canonical name : chamfer or splay concavity : 0
<i>Canonical round curves</i>	
	curve type: moulded canonical name : torus or half round concavity : 1
	curve type: moulded canonical name : cavetto concavity : -1
	curve type: moulded canonical name : ovolo or quarter round concavity : 1
	curve type: moulded canonical name : boltel concavity : 1
<i>Non canonical round curves</i>	
	curve type: moulded canonical name : segmental cove concavity : -2
	curve type: moulded canonical name : augmented torus concavity : 2
<i>Complex curves (more than one centre needed to draw the curve)</i>	
	curve type: moulded canonical name : cyma reversa or ogee concavity : -3
	curve type: moulded canonical name : cyma recta concavity : 3
	curve type: moulded canonical name : 3-centre oval concavity : -3

	curve type: moulded canonical name : Grecian ovolo concavity : 3
	curve type: moulded canonical name : scotia concavity : -3 (uses four centres in this redrawing from E. Barberot [6])

C. The knowledge modeling issue

Initially tested out on ceilings structures (Fig. 12) the visualisation handles multivariate data - integrating numerical, ordinal and categorical data - with a symbolic encoding combining various techniques (size, length and height, colour and icons, spatiality) into one multidimensional dashboard.

Among the profile's features, at this stage segments, time slot, and elements of architectural semantics are encoded visually. But the visualisation also delivers indicators read from operations on the features (orientation of each segment, global proportion, numbers of hidden / unmoulded / moulded segments, lengths of unmoulded / moulded segments when compared to overall length). On the overall a dozen of parameters are taken into consideration in the making of the visualisation called hereafter visual notation. Our first challenge in designing it was to address the scale issue. Let us make this point clear. Each segment in a profile's list of segments is defined by two control points. We could use the segment's real length, i.e. the distance in XY plane between the two control points, in order to show the relative importance of each segment inside the list.

This works quite fine when comparing objects of the same type, and of similar sizes. But when comparing objects that strongly differ in size (think for instance of lierne ribs and bases of pillar in gothic cathedrals), values for these lengths or distances will range from 1 to 10 or more. Representing the real distances between control points in a visualisation aimed at enhancing comparisons would over-emphasise differences in size and poorly support the reading of what we want to spot: rhythms and proportions.

As an answer, we express all segments of a profile - whatever their real dimensions are - inside a predefined gauge, the height of which representing the profile's longest segment. Graphically, a fixed-width rectangle represents each segment: its height corresponds to a ratio of the longest segment (Fig. 9).

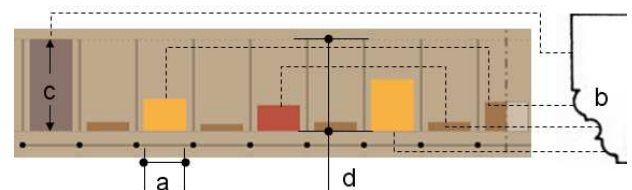


Figure 9. Each segment (b) is represented by fixed-width rectangles (a). The height of a rectangle is a percentage of a fixed gauge (d) corresponding to the profile's longest segment (c). Colours differentiate unmoulded segments (grey) from the

actual moulded elements (yellow, brown, red). Note that for readability purposes the original chromatic palette of the graphics may be altered in the examples given in this paper.

What is perceived then are the relative importance of each segment inside the composition, not their actual size. “Graphical integrity”, to quote E.R Tufte, is preserved (fixed width – lie factor 1 [34]) provided our claim is not a dimensional comparison, but a compositional comparison.

Colours used for fixed-width rectangles help spotting alternations of concave (red), convex (yellow) and flat curves (brown). They represent the sign before concavity attribute’s value. A line of symbols above the rectangles represents the numerical value of the of the concavity attribute (Fig. 10).

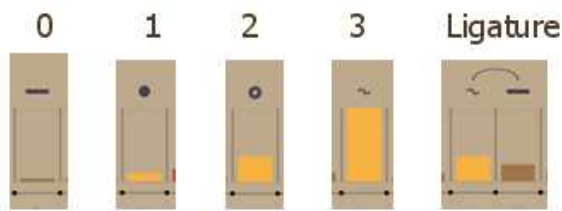


Figure 10. From left to right, symbols representing the numerical value of the concavity attribute: flat, canonical round curve, non canonical round curve, complex curve, and a ligature between a complex curve and a flat curve.

The visualisation is composed of two information groups, read from left to right, corresponding to a move from a general analysis to a close view of segments (Fig. 11).

It is a linear, horizontal graphic composition (designed so as to facilitate vertical comparisons between different profiles when putting one above the other, as will be shown in section IV). The first information group, *global profile analysis*, gives four indications:

- an icon representing a figurative view of the profile (i.e. a cross section of the 3D object, Fig. 11a),
- a global proportion assessment (comparison of the profile’s bounding box to a square, Fig. 11b),
- an icon used to identify the profile’s generation mode (translation/rotation/combined, Fig. 11e),
- a ratio representing “how much the profile differs from its bounding box”, (Fig. 11c) (measured by averaging distances of the moulded part’s control points to the profile’s virtual corner - the corner it would have had there been no mouldings - and then comparing the resulting number to the bounding box, Fig. 11d). At this stage, this ratio poorly performs (variations insufficiently rendered).

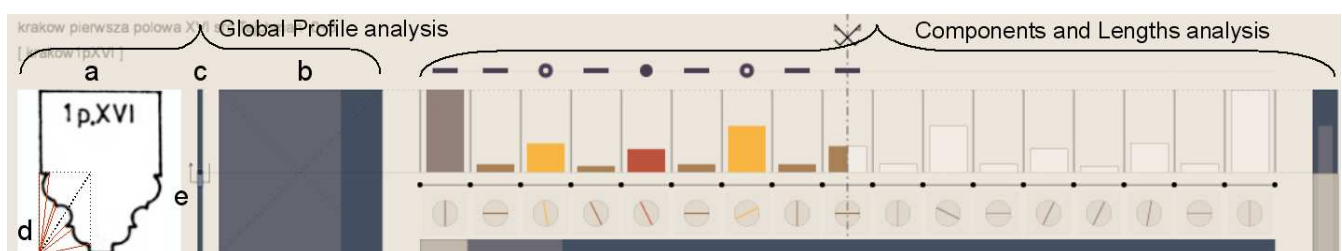


Figure 11. Left - global profile analysis information group, right - analysis of segments.

The second information group, *components and lengths analysis*, is divided in four horizontal indicators with a fifth one acting as a vertical boundary marking for the whole visualisation. Indicators on Fig. 12 show, from top to bottom, rhythms and moulding complexity (a), proportion and concavity (b), segments orientation (c); number of hidden / unmoulded / moulded segments (d), lengths of unmoulded / moulded segments when compared to overall length (e).

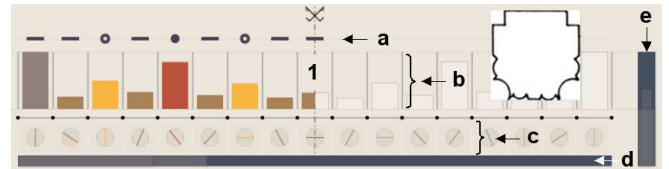


Figure 12. Components and lengths analysis information group - Due to this profile’s symmetry feature, an icon (1) is displayed, rectangles on the right side of the symmetry axis are whitened and rhythm line interrupted.

Finally, a timeline positioning the data info runs underneath the composition (Fig. 13 - 3). An analysis of the visualisation using Bertin’s graphic variables shows the following correspondences:

<i>Rhythm and moulding complexity (value of the concavity attribute)</i>	Shape
<i>Proportions of segments (ratio to the longest)</i>	Dimensions of rectangles
<i>Sign of the concavity attribute</i>	Colour of rectangles
<i>Orientation of segments</i>	Line orientation
<i>Numbers of segments</i>	Colour value

Illustrated below on an example from [22], the visualisation duly underlines the alternation of concave/convex curves the

author spotted, and in addition other patterns (ex. systematic insertion of a flat curve (Fig 13 - 7) between convex and concave curves - typical of gothic wooden ceilings, in contrast with gothic stone arches – Fig. 5, 6, 7).

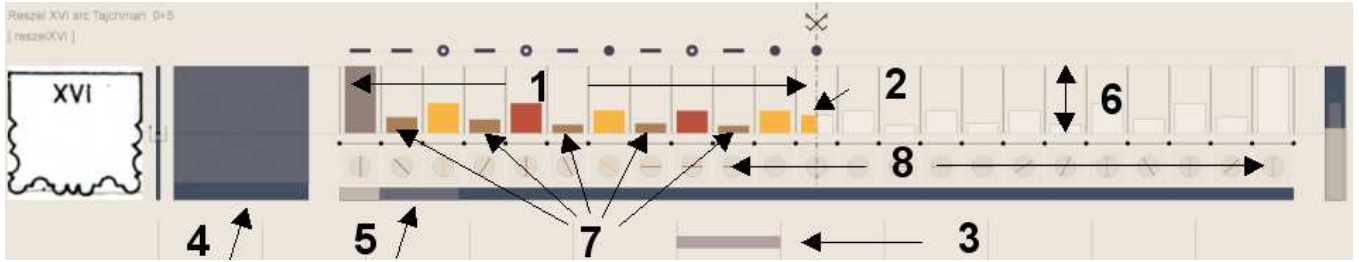


Figure 13. Visual support of Tajchman's indicators: number/concavity or curves (1), segment type on axis (2), dating (3) (XVIth century ceiling in Reszel). The visualisation supports Tajchman's description grid, and supplements it with variables such as global proportion (4), amount and percentage of unmoulded segments (5), proportion of each segment (6), nature and proportion of transitions between curves (7), orientation of segments (8), etc.

IV. Implementation and evaluation

The implementation's central element is a concept called MetaProfile (a class in the sense of OOP), that stores features of an object's profile and calls various modules. It does not need 3D data, except an optional 3D origin that can help understanding relations of the profile to the observer's position. For each 3D object to study, an instance of MetaProfile is created - using metric data that can be acquired as a result of 3D survey or extracted from 2D graphics [19]. A method of the MetaProfile class is in charge of reading an ASCII input (list of control points plus indication of symmetry when relevant) and of writing an XML formatted output that will act as root of persistence of the instance.

A number of tools classes that control the collection of instances, and dynamically write the outputs are also implemented. The platform accordingly supports incremental data update. The whole architecture is, as can be seen, rather straightforward, and strictly limited to the use of freeware / opensource solutions (XML / XSL / XHTML / Jscript / Perl / SVG) that have successfully been combined in numerous experiences (ex. [35],[19],[36]). At this stage of our research, two types of evaluation have been carried out: a readability assessment test (disposal's cognitive load, possible ambiguities, targeted at newcomers in the field) and an efficiency assessment analysis (benefits expected vs benefits on real cases). It must be said clearly that these two initiatives do not stand for a through, in-depth evaluation of the framework; we therefore make no general claim on its value. Our point in this contribution will mainly be to show that there is food for thinking in bridging architectural modelling and information visualisation [18].

A. Readability assessment

In short, our approach implies the "slicing" of a profile into individual components, individual features, and a visual encoding of components and features. To which extent can the resulting graphic still be perceived as a representation of a

profile? In order to obtain a preliminary answer, we asked testers to match icons representing figuratively cross sections of profiles, and the visual notation (Fig.14). Testers were last year students in mechanical engineering, and therefore had a

background neither in architecture nor in humanities in general. Tests included three successive steps: a ten minutes blackboard presentation of the framework, the pair matching test itself (on seven profiles relatively similar – same type of object, same stylistic affiliation), and an interview during which we asked testers what strategy they used to do the matching (what feature they read first for instance, or how they disambiguated the most similar profiles).

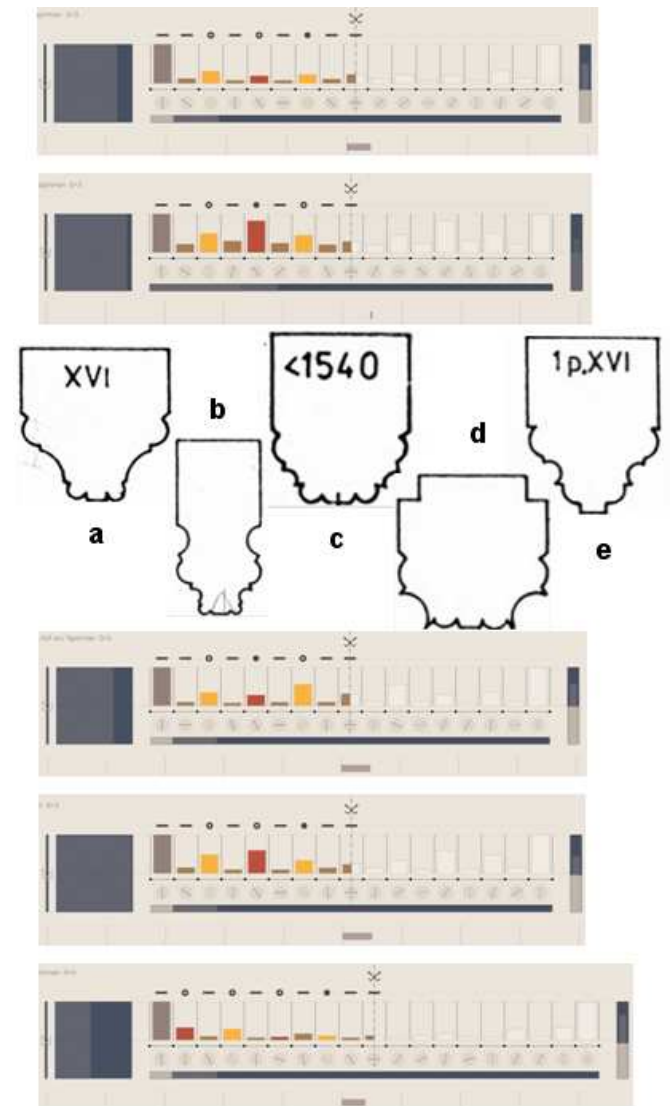


Figure 14. Principle of the pair matching test: cross sections and the corresponding visualisations are presented separately. Testers are left free to choose a strategy in order to match pairs. Examples chosen cannot be disambiguated without

adopting successive strategies that testers have to verbalise (only a selection of examples provided to the testers are shown here). In this case for instance the pair (object b, line 5) can easily be spotted basing on the global proportion. But on lines 1 and 3, as well as on lines 2 and 4, global proportions are too close to make a difference. Accordingly testers relied on other features (answers here are: a4, b5, c1, d2, e3).

Results do call some remarks. None of the testers made any mistake in matching pairs. This does not mean the disposal is fully satisfactory, but it shows the features chosen, and the encoding, perform quite correctly as far as disambiguation is concerned. More interesting, the interviews showed varying strategies: a majority of testers started with a reading of the global proportion indicator (Fig. 11b), but they then chose either the rhythm line (Fig. 12a), the proportion line (Fig. 12b) or the number of hidden / unmoulded / moulded segments (Fig. 12d). By contrast, they overwhelmingly ignored the orientation line (Fig. 12c) and the lengths of unmoulded / moulded segments indication (Fig. 12e). These varying behaviours can be interpreted positively by saying “the disposal is adapted to various reasoning modus” or negatively by saying “the disposal is too complex to be universally read”. The limited number of testers and the triviality of the test make both these conclusions rather premature.

B. Efficiency assessment analysis

We hereafter present a variety of applications of the framework to real cases, in order to illustrate its possible benefits- as well as situations where it may not perform satisfactorily. The framework’s performance is evaluated through cases chosen inside respected analyses of historical architecture. This exercise allows us to comment expected benefits in a consistent context (i.e. minimising what archaeologist call the source effects).

1) Supporting the identification and visualisation of patterns, spotting exceptions.

The visualisation performs here quite well, with for instance a clear-cut visual transfer of Jan Tajchman’s analysis of ceilings (Fig. 15) or on gothic profiles by [7].

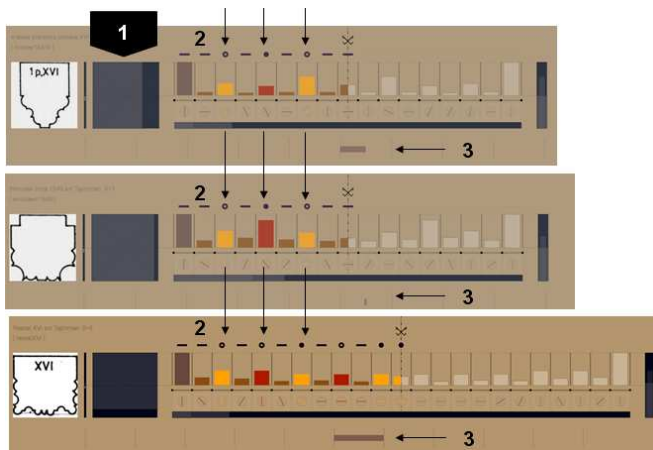


Figure 15. In this comparison of three profiles of beams note that although global proportions do vary (1), rhythms of these profiles are undeniably comparable (2). This observation is unsurprisingly consistent with the dating (3) of these profiles.

Also tested on an analysis of decorative tendencies during the Romanesque period [13] (Fig. 16) the notation does underline decorative patterns, as well as unexpected differences.

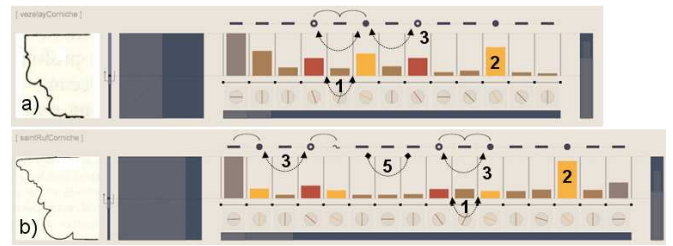


Figure 16. In his analysis of decorative tendencies during the Romanesque period, A.Choisy chooses to compare profiles of cornices of various “schools”, here in a) the Clunisian school (Vézelay) and in b) the Provence school (Saint-Ruf, near Avignon).

In A.Choisy’s words, when comparing the above profiles, “*the feeling that there is here a common sense of decoration is absolute*”. And indeed the notation underlines clear decorative patterns:

- (1) Ligatures between a convex and a concave curve through a chamfer.
- (2) Predominance (in size) of the bottom most convex curve.
- (3) Use of non canonical round curves for concave curves, and of canonical round curves for convex ones - read on the rhythm line with circles unfilled (non- canonical) and filled (canonical).

In (5) fillets of case b) appear as a discordant feature.

2) Measuring visually changes over time inside a family of objects, and inside a style

We tested here a comparison of Greek Dorick capitals—examples of Metaponte, Tarente and Parthenon [13]. The author describes the evolution of the ovolo from a rounded curve to a straight one. Our observation confirms this evolution - the ovolo being replaced as longest curve in the notation by the abacus (Fig.17).

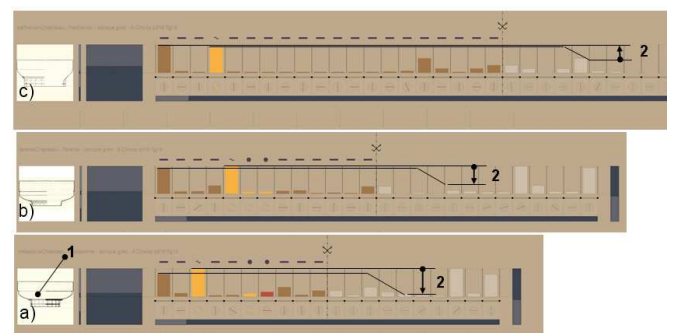


Figure 17. Evolution of the ovolo (1) from a rounded curve to a straight one, proven by changes in distance (2) : in a) the ovolo is the longest curve, in c) the abacus has become the longest curve.

3) Measuring visually changes in an object’s composition and rhythms across styles.

Experienced in a comparison of column bases (classical orders) [6], the visualisation helps portraying a pattern of evolution by supplementing traditional differentiation based on the number and types of components with the reading of

proportions and rhythms. The number and types of components do appear, and unsurprisingly reflect a basic “complexification” pattern.

But the visualisation also helps underlining other features: although the number of moulded components is multiplied by three, global proportions of the objects remain very close, rhythm and proportion of the bottom torus and plinth are also almost unchanged, and the scotia in the Ionic base appears as inserted in between elements already present in the Doric base (Fig. 18).

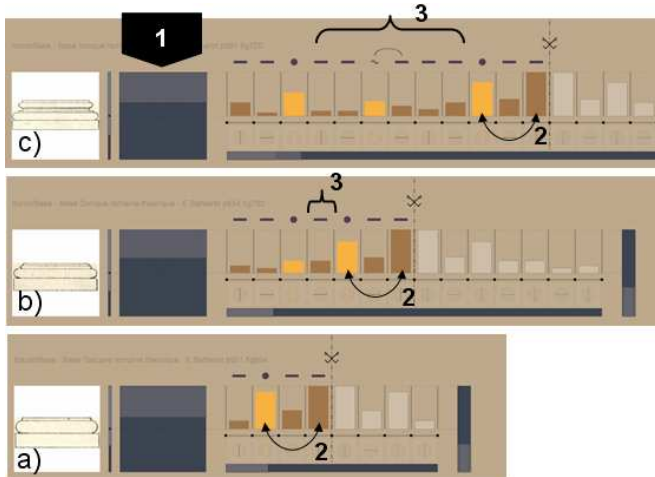


Figure 18. Barberot’s theoretical composition of Roman bases for (a) the Tuscan order, (b) the Doric order and (c) the Ionic order [6]. The visualisation helps underlining what remains, and what changes:

- (1) Although the number of moulded components is multiplied by three, global proportions of the objects remain very close.
- (2) Rhythm and relative proportion of the bottom torus and of the plinth it stands on also appear almost unchanged.
- (3) The scotia in the Ionic base clearly appears as inserted in between elements already present in the Doric base: composition and proportion of the components to the left and the right of the parenthesis are similar.

4) Enhancing the readability of qualitative, rhetoric differentiation across regions or styles.

In his description of early Christian architectures, A. Choisy [13] uses terms like “elegance” or “flabby” that may be suitable to the needs of literature, but can hardly be transferred into an objective observation grid.

We tested here the visualisation on four cornices corresponding to early Christian schools: a) Syriac, b) Byzantine, c) Latin, d) Armenian (Fig. 19). Let us here make it clear that our attempt was not to map terms to metrics, but to try and understand what observations lead authors to choose this or that term.

Said briefly, in three out of five cases it appeared possible to back up Choisy’s arguments by observations on the visualisation – but nothing tells us how far we are here from plain wishful thinking. The visualisation should clearly not pretend replacing or even fully transferring an author’s qualitative, rhetoric analysis.

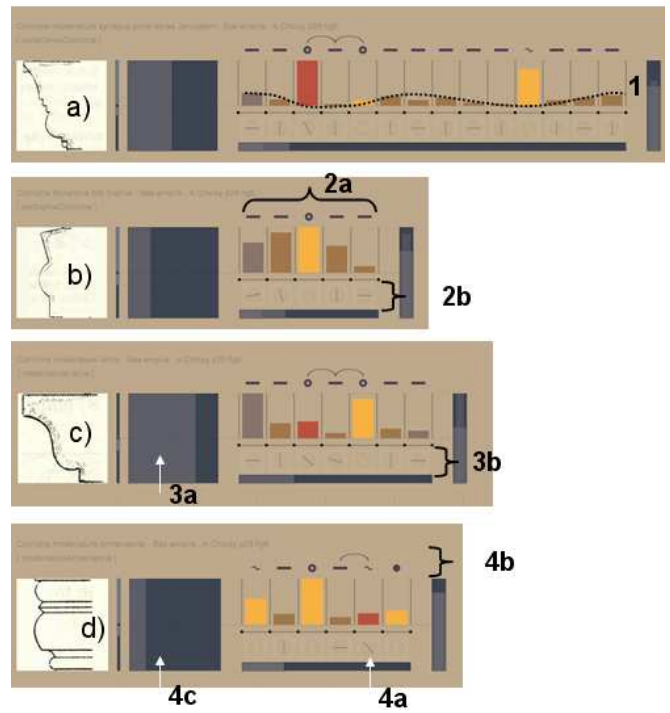


Figure 19. a) According to Choisy, this Syriac cornice shows “skilful alternation of movement and pauses” - Whether it is skilful or not we shall not comment, but his idea does seem to match patterns: large complex curves, inside a net of smaller and unequal flat curves creating (1) a wave effect not that obvious when looking at the actual section.

b) Only the adjective “angular” is here used by the author, maybe because of the simplicity of the profile - we shall here draw no real conclusion although the visualisation does underlines proximities in proportions (2a) and an uncommon pattern of segment orientation (2b).

c) According to Choisy, a “flabby and round” decoration - The global proportion (3a, far less vertical than others), the 2/3 proportion of curved and flat mouldings, as well as the ligature connecting curves, can appear as backing up his view. The orientation line (3b) may also be an argument: both curves are inclined. Yet this profile is a very simple one, and in no case does allow a clear conclusion.

d) The Armenian profile’s “elegant baldness” is backed up by several indicators: only one inclined curve, and the only concave one (4a) - a majority of non-canonical and complex curves (4b) - a very vertical proportion (4c). Elegance would lay in the nature of the curves, and baldness in the profile’s verticality? We may conclude here that sometimes words say more than figures...

5) Measuring visually and transferring into metrics qualitative descriptions of patterns.

In a chapter entitled “Profiles” of his dictionary [7] Viollet Le Duc says “starting from circ. 1240, methods employed to draw profiles are more and more bounded by geometrical rules and regular measures”.

But his demonstration on transverse arches is far from being only rhetoric – and the visualisation in that case does confirm two of his statements, and moreover helps understanding the metaphor he uses when he writes “Architects in Burgundy respected grammar and syntax [of architecture] but they had their own turns and pronunciation” (Fig. 20).

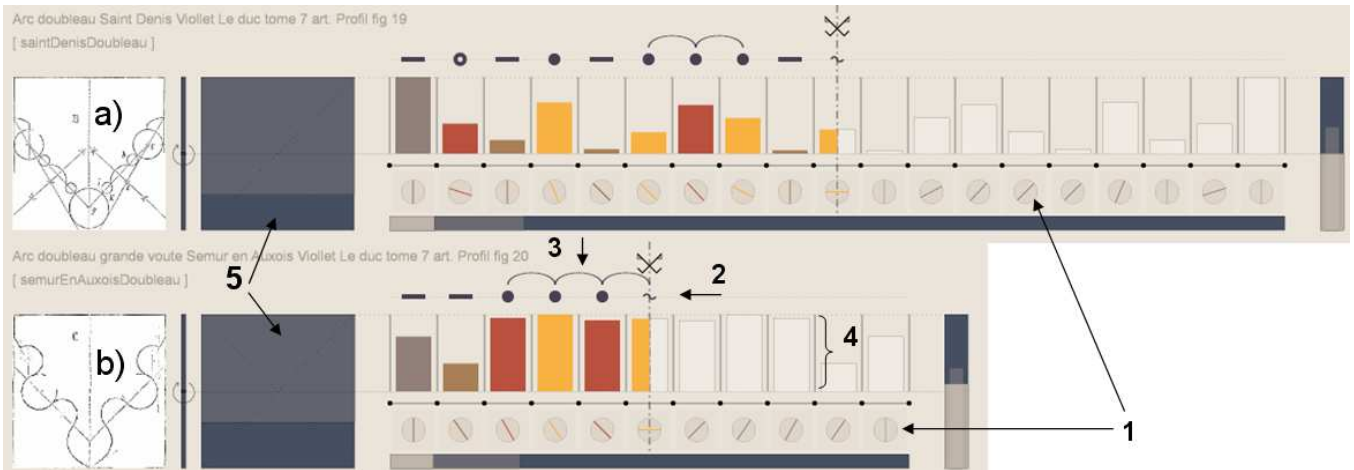


Figure 20. E. Viollet Le Duc underlines the use of simple angles (60/45/30°).

In (1) the orientation line does confirm his remark on these two examples: a) Saint Denis and b) Semur en Auxois.

Another statement by Viollet Le Duc finds a confirmation when he writes “the method [tends to get] simpler and simpler” when observing profile b) : flat segments between curves are replaced by ligatures linking curves (3), both concave and convex curves are canonical round curves (2),. Viollet Le Duc writes “Architects in Burgundy (case b) respected grammar and syntax [of classical Ile De France gothic architecture, case a)] but they had their own turns and pronunciation” [7].

The visualisation does provide useful hints about what these “turns and pronunciation” could be: a majority of ligatures linking curves (3), use of are canonical round curves only (2), regularity of proportions of curves (4) inside a global proportion that remains approximately the same (5).

6) Understanding geographical/ethnic variants inside a family of objects, a style and a political continuum.

The comparison of a capital of the Doric theatre of Marcellus in Rome and what Choisy describes as a variant of the roman Doric in Gaul showed more differences than similarities (number, type, orientation of components, rhythms and proportions) [13].

What the visualisation helps us to understand here is that the word Doric, used to qualify both these capitals, should be restricted to denote only a historical co-conception. The notation underlined deep architectural differences - intuitively visible, but here proven by factual indicators (Fig. 21).

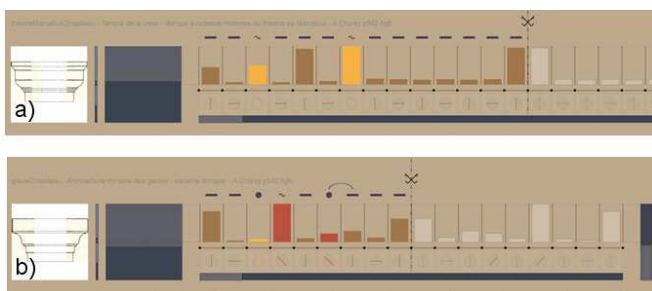


Figure 21. Comparison of capitals in (a) theatre of Marcellus and (b) a variant of the roman Doric in Gaul shows differences more than resemblances:

- number of components (note for instance that Greek annulets remain in a, but are replaced in b);

- type of components (two complex curves in between flat curves in a), introducing canonical round curves in b), and ligatures)

- orientation of components (although all flat curves are in both cases either horizontal or vertical, b introduces a vertically oriented canonical round curve);

- rhythms (note stronger irregularity in b);

- concavities (still only convex in a; introducing a majority of concave in b);

- proportion (still less than 1/2 in a , more than 1/2 in b).

7) Verifying hypothetical schemes of influences.

Quoting predecessors in history of architecture, A. Choisy considers Syrian architecture during the early Christian period as a root of influence over Romanesque architectures (relations due to pilgrimages) – tested here on cases he quotes in Normandy and in the Clunisian school (Fig. 22).

A close look at the result does show some evidence of his statement for the latter case - but not in the former where differences outnumber similarities by far. At this stage the experiment should be considered as inconclusive.

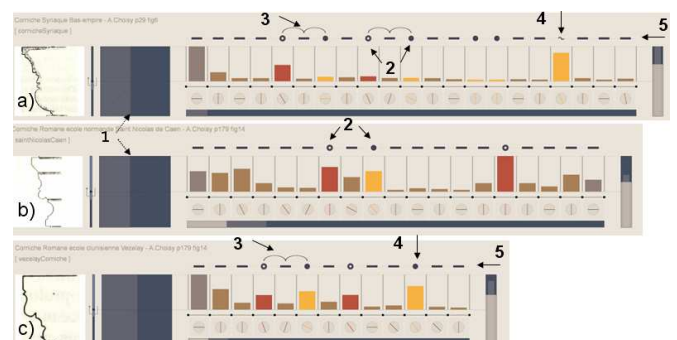


Figure 22. Influence of Syrian architecture (a) during the early Christian period over Romanesque architectures in Normandy (b) and Clunisian school (c).

Case a) and b) : Only bbox proportion (1) and use of non-canonical concave curves / canonical convex curves (2) do compare. On the contrary, b) has more concave than convex curves, no ligatures, and a stronger majority of flat curves with as consequence a rather dull rhythm line.

Case a) and c) : More features do compare: ligatures between a convex and a concave curve through a chamfer (3); predominance (in size) of the bottom most convex curve (4), and a rhythm line of c) more comparable to a) than b) (5).

V. Conclusion

The methodological framework and its implementation have, at this stage, limited ambitions, in particular in terms of technical impact. However we consider its most significant limits are the following elements:

- The a priori reduction mechanism itself (each moulding seen as a segment between two control points) is the major one. Our claim is that this modelling bias helps analysing patterns and exceptions in rhythm and proportion, but we acknowledge that it is a loose fishing net, not replacing a thorough geometric investigation (to capture for instance local shape deformations).
- The architectural theory sometimes relies on allegories or figures of literature – and these are hardly transferable in metrics and visual encoding, even at an abstract level. However what we try to compare are profiles, not discourses about profiles, and therefore this limit might be acceptable.

Practical limits also can be quoted on the result as it stands:

- Real sizes of objects under scrutiny are at this stage absent from the visualisation. A switch from corrected – gauged – dimensions to real sizes could probably be fruitful, and needs to be tested.
- Other indicators read from the cross-examination of attributes (ex. geographical markers) are also missing in the visualisation. In short encoding possibilities have not all been reviewed.

Yet in our view the next step should privilege a more comprehensive evaluation procedure, before any re-intervention on the components of the visualisation. Beyond, future works should first focus on developing collection-reading mechanisms, in particular on spatialising the observations so as to uncover possible convergences or exceptions inside consistent groups of objects (Fig. 23, 24).

Other future developments should be carried out in order to facilitate the browsing the underlying data sets, and ultimately on supporting the post-processing of survey results, notably in the following steps: automatic acquisition of data (feed inputs automatically), automatic classification of profiles, and automatic detection of patterns and exceptions.

In addition, a tempting although anecdotal development would be to use the framework as a design tool rather than as an analysis tool – designing at an abstract level the composition of profiles.

The framework introduced in this paper appears relatively efficient in gaining a synthetic, abstract view of profiles, thereby facilitating the analysis of tendencies and discordances, and the comparison of profiles. It can be adapted to inputs that may range from results of 3D surveys to archival 2D graphics as they may exist in literature or previous investigations. The framework performs correctly in assessing visually notions like rhythms, alternation of concavities, proportion, spotting of discordant behaviours – all notions poorly supported by existing geometric modelling solutions. As a side effect, it also underlines the “relative accuracy” of theoretical analyses found in literature.

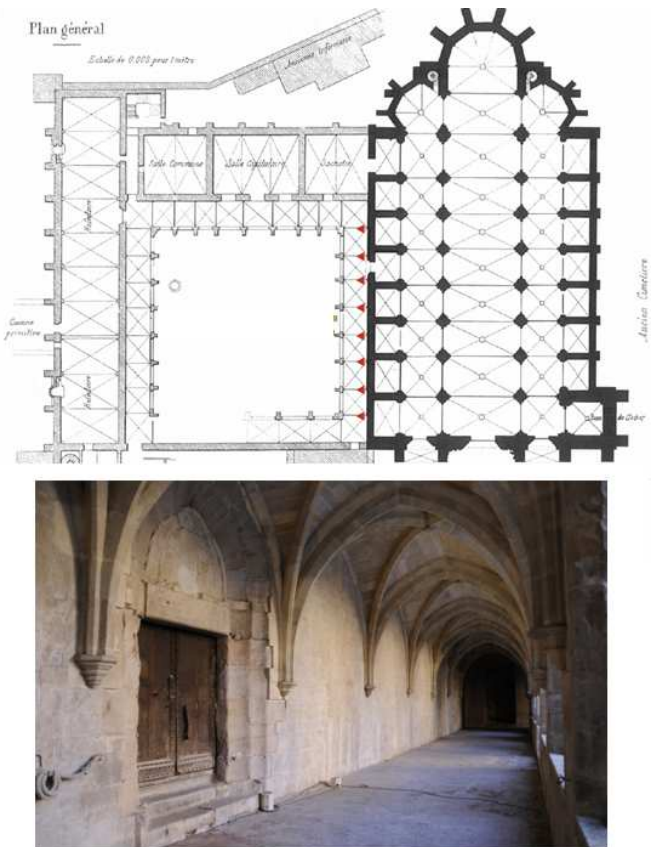


Figure 23. An attempt at spatialising observations on a line of eight corbels of the gothic cloister in Saint Maximin's basilica. Top, position of the corbels on a XIXth plan of the basilica and of the convent ensemble, bottom, the actual alignment of corbels along the church wall of the south aisle.

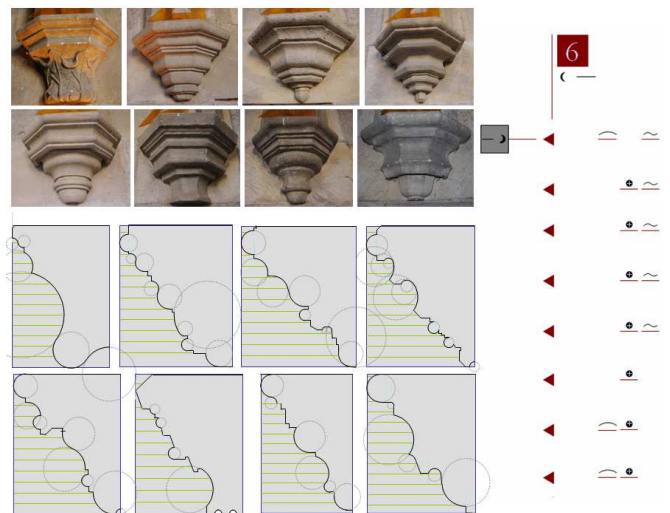


Figure 24. Top, a front view showing the eight corbels, and bottom, the Profile once extracted from our survey (Photomodelling). These undocumented 3D objects do “look different”; and in this case, the visualisation was used to try and uncover a common pattern, or common prescriptions. As a result, we did point out common features that are represented on the right figure through symbols on the left and on the right of a line of triangle that stands for the spatial distribution of the corbels. Among these features is the overall number of non-flat curves (6), a majority of canonical curves except in the first corbel, a systematic use of complex curves down to the sixth corbel, etc. At this stage, the visualization does

nothing more than deliver a new hint, a new clue, that needs to be cross-examined with historical evidence.

The experiences conducted showed that going abstract can help us gain a “context and focus” view over mouldings in historic architecture, *i.e.* an acute view of individual features within mouldings (concavity, proportion of each curve for instance), and a panoramic view of mouldings (encompassing typological, geographical and temporal distribution). However the framework’s role is not to replace 3D surveying and geometric analyses.

Its role as we see it is to complement them with a synthetic vision of profiles, fostering cross-examinations in a straightforward manner, and putting profiles in a context where their relation to the theory of architecture is assessed.

More than a century ago, mathematician H.Poincaré wrote in his “*value of science*” [37] that “*science [...] is a system of relations. [...] it is within relations that objectivity should be searched for, it would be vain to look for it in objects considered as isolated from one another*”.

In this contribution, we hope we have demonstrated his view fully applies to heritage architecture analysis, if not to historical sciences in general. Although relations might here be thin – due to irregularities, uncertainties, imprecision that are typical of historical data sets, Poincaré’s vision can still be a fruitful guideline in a multidisciplinary investigation where heritage architecture modelling issues meet visual analytics.

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