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# ANALYSING ARCHITECTURAL MOULDINGS WITH 3D OBJECT-INDEPENDANT METRICS AND ENCODING

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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, patterns, heritage architecture, comparative reading.

## 1. 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 [Papadopoulos, 2008], promote spatial information management systems [Van Ruymbeke, 2008] or facilitate the acquisition and representation of metric data [Lo Turco, 2009] and understand its impacts in the field of the cultural heritage [Alkhoven, 2006] [Lucet, 2008]. 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.

Broadly speaking, the architectural theory identifies on one hand individual components (Fig1a) – such as ovolos, ogees, etc. – and on the other hand canonical combinations (Fig1b), often considering the latter as time markers (Fig1c). *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 going abstract, in 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.

## 2. RESEARCH CONTEXT

Mouldings are a fundamental part of the architectural theory, mentioned since the first treaty of architecture by Roman architect Vitruvius, intensively used in historic architecture [Palladio, 1965], [Wittkower, 1998], and still present in nowadays catalogues of ornamental components [Ching, 1996]. However defining what they are is not that easy. [Harris, 1983] 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. We introduce three notions:

- an underlying 3D object (“member of construction”, Fig 1c),
- a profile consisting of “varieties of outline or contour” (Fig 1d),
- individual components “on projection or cavities” (Fig 1a), with alternating edges and surfaces.

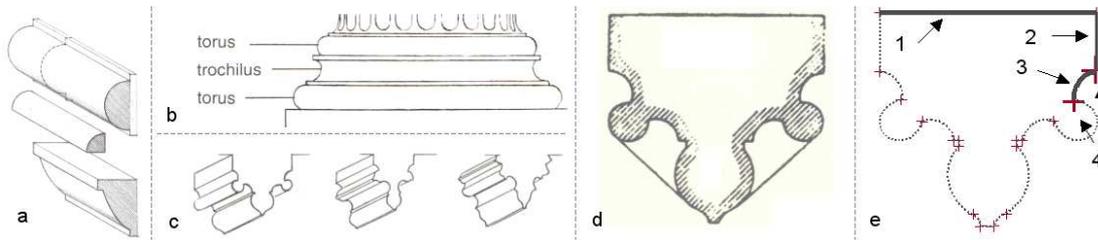


Figure 1. a) individual components – here half round, quarter round, *ovolo*, [Ching, 1996]; b) a canonical *attic base* combination, [Koch, 1996]; c) underlying 3D objects (here arches) with 3 combinations representing steps in the gothic trend’s evolution [Koch, 1996]; d) a profile [Choisy, 1991] – e) components of a profile classified as : contact (1), unmoulded (2) and moulded (3) segments, each between control points (4)

Methods and tools available to study and compare mouldings remain mainly qualitative (Choisy describes profiles with words and 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. 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, that 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 [Bertin, 1998] to Tufte’s visual explanations [Tufte, 1997], 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 [Kienreich, 2006]. In this contribution focus will be put on the “acquisition of insight into abstract data” [Spence, 2001] – 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, [Tajchman, 1989] 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 2). In that sense, Tajchman already introduced this *abstraction level* we believe is needed. 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:

- differentiation, labelling and reading of proportions of each segment, with support for angular ranges,
- a unique description models 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).

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 – post-processing of raw survey results – has been raised in works like [Ramondino, 2003] [Gonzalvez, 2007], but it remains today a hot research topic. Our position [Blaise, 2009], 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.

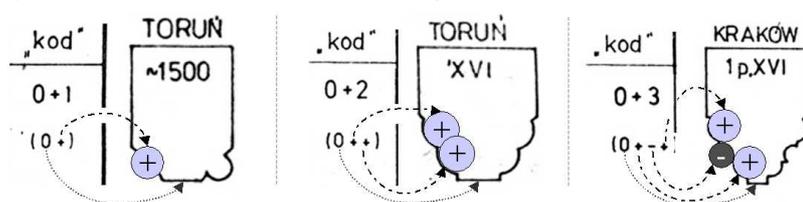


Figure 2.: Profiles for Group O, codes 0+1, 0+2, 0+3 of Tajchman’s classification – as can be seen 0 refers to profiles with a flat bottom segment, and concavity is counted in a binary +/- mode (drawn over Tajchman’s original graphics)

### 3. OBJECTIVE & SCOPE, METHOD, CONSTRAINTS

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 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. The global objective - a methodological framework – should therefore be divided into three distinct 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 [Blaise, 2009].

#### 3.1 The knowledge modelling issue

The somehow ambiguous notion of “mouldings” (supposedly 3D, but mostly represented in literature by a 2D cross-section, its only normative aspect) is transferred into a concept called MetaProfile, described by:

- a list of segments (themselves concepts described by various attributes),
- a time slot and a geographical position (toponymy),
- geometric inputs (optional, allows handling of the object in 3D), along with its sources,
- elements of architectural semantics (ex. style, 3D-shape generation mode, symmetry, ontology),

We thereby define mouldings at an abstraction level where 3D data is optional. We reduce (in the sense of [Francis, 1999]) 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 [Blaise, 2008]). The profile 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 (Fig 3a). A segment is defined by a set of qualitative or quantitative attributes - curve type and canonical name, ex. lexical scales; control points (Fig

3b); concavity (Fig 3c), numerical scale. Segments can correspond to contact surfaces (Fig 3c, 5), visible but unmoulded surfaces (Fig 3c), or may correspond to one of the profile's curves (Fig 3c - 1, 2, 3) – individual canonical components as defined in the architectural theory.

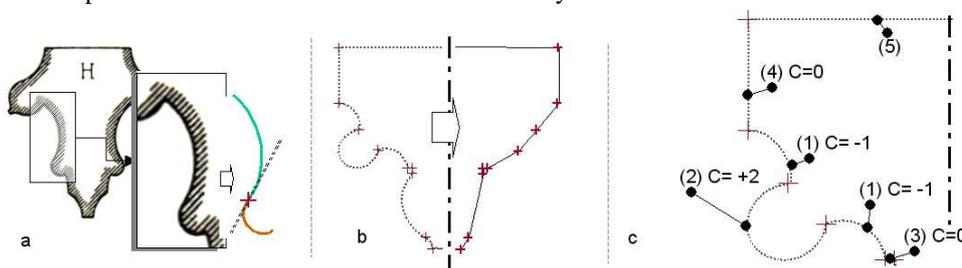


Figure 3. a) Example of a ligature, a common marker of the Gothic period, where a control point does not correspond to a vertex but is located at a voluntary tangency point, [Choisy,1991]; b) the profile reduced to a list of control points and segments; c) a numerical scale called moulding complexity is used to differentiate concave (-), convex (+), and flat curves, (0 - flat curve, 1 - canonical curve, 2 - non-canonical round curve, 3 for complex curve)

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. 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. 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.

### 3.2. The knowledge/info visualisation issue

Tested out on ceilings structures (Fig 5) 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 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 the most: 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. 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) provided our claim is not a dimensional comparison, but a compositional comparison. The visual notation 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 4). The first information group gives four indications:

- an icon representing a figurative view of the profile (*i.e.* a cross section of the 3D object, Fig 4a),
- a global proportion assessment (comparison of the profile's bounding box to a square, Fig 4b),
- an icon used to identify the profile's generation mode (translation/rotation/combined, Fig 4e),

- a ratio representing “how much the profile differs from its bounding box”, Fig 4c (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 4d). At this stage, this ratio poorly performs (variations insufficiently rendered).

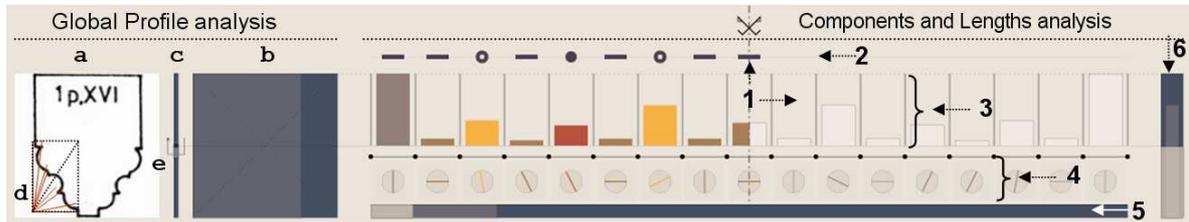


Figure 4. Left - general information group, right - analysis of segments. Due to this profile’s symmetry feature, an icon (1) is displayed, rectangles on the right side of the axis are whitened and rhythm line interrupted.

The second information group is divided in four horizontal indicators with a fifth one acting as a vertical boundary marking. Figure 4 shows, from top to bottom, rhythms and moulding complexity (2) (*cf.* Fig 3c), proportion and concavity (3), segments orientation (4); number of hidden/unmoulded/moulded segments (5), lengths of unmoulded/moulded segments when compared to overall length (6). Finally, a timeline positioning the date runs underneath the composition (Fig 5.3). Illustrated below on an example from [Tajchman, 1989], the visual notation duly underlines the alternation of concave/convex curves the author spotted, but in addition underlines other patterns (ex. the systematic insertion of a flat curve (Fig 5.7) between convex and concave curves - typical of gothic wooden ceilings, in contrast with gothic stone arches – Fig 1d, 3a).

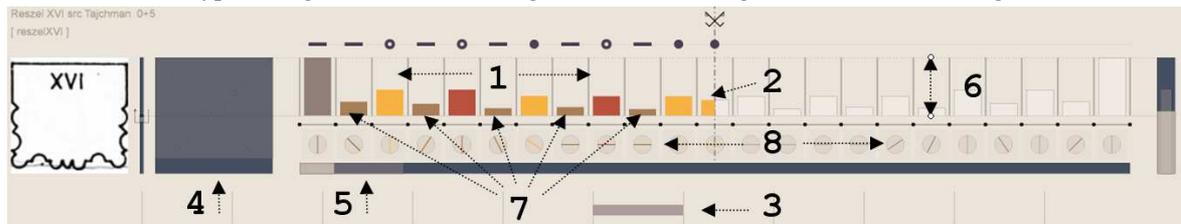


Figure 5. Visual support of Tajchman’s indicators: number/concavity or curves (1), segment type on axis (2), dating (3) (XVIth century ceiling in Reszel ). The notation supports Tajchman’s description grid, and supplements it with more variables such as global bbox proportion (4), amount and percentage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

## 4. IMPLEMENTATION & 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 [Blaise, 2008]. 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. [Rathert, 2005]). 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.

## 4.1. Readability and benefits 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. More precisely, 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). 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 4b), but they then chose either the rhythm line (Fig 4.2), the proportion line (Fig 4.3) or the number of hidden/unmoulded/moulded segments (Fig 4.5). By contrast, they overwhelmingly ignored the orientation line (Fig 4.4) and the lengths of unmoulded/moulded segments indication (Fig 4.6). 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.

We present in the following table an analysis of the framework’s performance on real 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).

### 4.1.1 Supporting the identification and visualisation of patterns, spotting exceptions

The visual notation performs here quite well, with for instance a clear-cut visual transfer of Tajchman’s analysis of ceilings (see Fig 5) or on gothic profiles by [Viollet Le Duc, 1856]. Also tested on an analysis of decorative tendencies during the Romanesque period [Choisy, 1991] (Fig 6) the notation does underline decorative patterns, as well as unexpected differences.

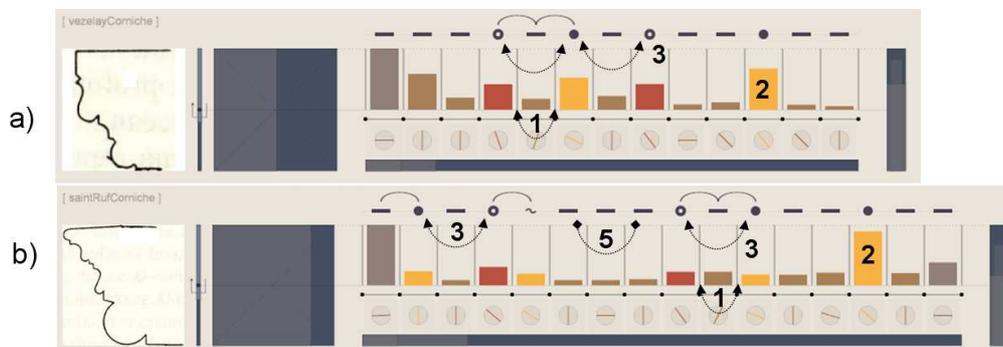


Figure 6. Cornices of various “schools” a) the Clunisian school, Vézelay; b) the Provence school, Saint-Ruf; The notation used to identify, behind what Choisy calls “a common sense of decoration”, objective common patterns. (1) ligatures between a convex and a concave curve through a chamfer; (2) predominance (in size) of the bottom most convex curve; (3) use of partial circular curves for concave curves, and of full circular for convex ones - read on the rhythm line with circles unfilled (partial circular curves) and filled (full circular curves). In (5) fillets of b) appear as a discordant feature

### 4.2.2 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 [Choisy, 1991]. 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.

### 4.2.3 Measuring visually changes in an object’s composition and rhythms across styles.

Experienced in a comparison of bases (classical orders) [Barberot, 1922], the notation 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 notation 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.

#### **4.2.4 Enhancing the readability of qualitative, rhetoric differentiation across regions or styles.**

In his description of early Christian architectures, Choisy 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 notation on four early Christian schools: a) Syriac, b) Byzantine, c) Latin, d) Armenian. 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 notation – but nothing tells us how far we are here from plain wishful thinking.

#### **4.2.5 Measuring visually and transferring into metrics qualitative descriptions of patterns**

In the chapter “Profiles” [Viollet Le Duc, 1856] 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 notation 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” – these “turns and pronunciations” appear to be a majority of ligatures linking curves, use of full circular curves only and regularity of proportions of curves.

#### **4.2.6 Understanding geographical/ethnic variants inside a family of objects, a style and a political continuum**

The comparison of 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). What the notation 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.

## **5. 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, on 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. 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.

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