Understanding Gothic Rose Windows with Computer-Aided Technologies

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This paper explains the parameters and methodology at the heart of an ongoing research project that seeks to verify whether one can trace back the genesis of any given artefact or work of art by means of computer-aided modeling. In its endeavour our research team Computer Assisted Design Research Group (GRCAO) aims to initiate and propose novel methods of modeling design processes. This approach is exemplified by a case study dealing with rose tracery designs adorning Gothic cathedrals of 12th and 13th Century Île-de-France. A computerized model reenacting their design process was developed along with an interface enabling the translation of the designer's intentions into a virtual design space. The stated goal of this research project is to evaluate empirically to what extent our modeling strategies can grasp a given artefact as a logical and articulate ensemble. Furthermore, we seek eventually to determine whether this kind of software programme would prove an adequate tool in the development of the architectural designer's cognitive abilities.

Keywords: *Architectural modeling; architectural know-how; Gothic rose windows; functional programming.*

Introduction

In the broad field of architecture, computers are currently employed to generate graphical representations of design concepts. Despite their ubiquitous presence within the discipline it is unlikely that computers are really put to use at their full capacity. After all, computers literally offer a whole virtual world that can unfold in time in a non-linear fashion. With the computer one should be able to place an architectural concept before the mind not only at certain fixed moments in its development, but also in the entirety of its relational process of generation, from the mind of its creator to its material execution.

Before it is materialized, an architectural idea is established, developed, and refined in the mind of the designer, though there is no trace left whatsoever of this internal mental process. Behind any given monument or artefact stands a creative process of great complexity and about which we are naturally curious. In our research we seek to determine whether the creation of any given artefact or work of art can be recovered and re-presented as a dynamic process, i.e., in its integral wholeness, by means of computer-aided modeling (Tidafi, 1996, De Paoli, 1999).

Our thesis is straight forward: we argue that with certain of the technological means available today we are not always obliged to content ourselves with fixed graphical representations of design ideas isolated from one another and from formative factors in time and space. Indeed, this has been the premise of the research project this paper reports. There, as here, we explore the possibility of a computerized simulation of the various phases of an actual architectural design process by means of an historical case study, the rose window configurations of Gothic church architecture.

The Gothic rose window

Along with pointed arches and flying buttresses, medieval rose windows have come to epitomize the

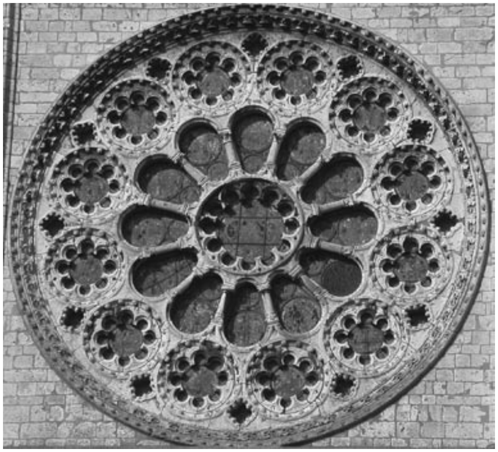

Figure 1
Western rose window, Chartres Cathedral, photograph by Dominic Boulerice.

Gothic cathedral. From the fairly modest-sized oculi – mere roundels often left unadorned – of Romanesque and Early Gothic churches, to the colossal tracery networks spanning some 12 metres on the Western façade of Chartres Cathedral, Gothic rose windows bear witness to the great technological know-how of medieval builders (Figure 1).

Our project seeks to trace in reverse the genesis of the Gothic rose window. The point of this effort is to understand, describe and model a design process that today is, at best, little-known and must be deduced from various sources, primarily the design product itself. Gothic rose tracery designs lend themselves particularly well to this type of compositional analysis: they were devised using straight-forward practical geometry and are basically two-dimensional in conception. They also comprise a well-circumscribed aspect of medieval design whose principles of design would have been readily grasped by practitioners who possessed little in the way of theoretical knowledge.

Rose window design was not, however, an effortless art. One must never lose sight of the fact that, while these circular stone tracery networks were designed in regard of their aesthetic, formal and symbolic effects, they were also obliged to respond to mechanical problems of support and load in a manner consistent with the well-known daring of their creators. All of these imperatives of contemporary design needed to be adroitly juggled in the conception of a window tracery. Certainly the creation of such designs called for deep experience, crafty calculation, vast knowledge and outstanding comprehension of the application of structural constraints in the general context of ornamental effect, as Viollet-le-Duc (1854-1868) correctly pointed out in his *Dictionnaire raisonné*.

Our working samples were chosen from among rose tracery designs of 12th- and 13th-century Île-de-France (Hardy, 1983). They range from simple oculi to double wheel-windows. Our primary interest has been to formulate the process most likely to have led to the realization of such designs, whose forms may be most easily understood as the result of the interlocking of solids and voids within an encompassing circular frame.

Understanding the design process

We undertook in our project a rigorous analysis of selected tracery designs so as to reconstruct their probable geometrical matrices. Although we have produced geometrical constructions describing the shape and contour of each and every voussoir, mullion and colonnette of the traceries under study, it must be emphasised that it was never our goal to replicate their exact geometrical forms, but rather to ascertain the logic of their design (Figure 2).

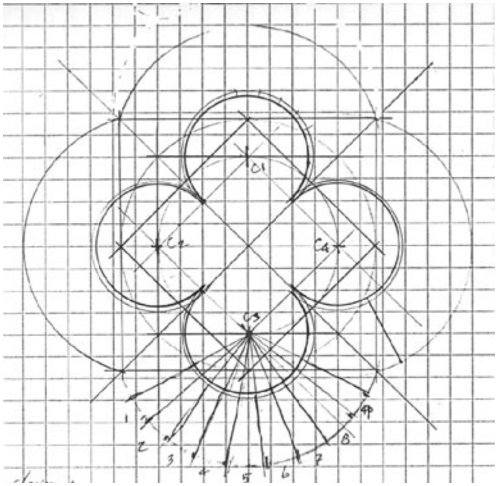

Figure 2
Geometrical study of quatrefoil (Oulchy-le-Chßteau), drawing by David W. Booth.

A medieval designer had to consider many issues in designing window tracery, including those chiefly of aesthetics, symbolism and construction. In reconstructing the rose design process, we needed to establish the various decisions taken by these designers and to arrange them in a logically interrelated sequence reflecting the increasing complexity evident in the historical evolution of the building form without becoming so attentive to particulars that we "failed to see the forest". This was tantamount to formalizing the know-how at the heart of Gothic rose tracery design. For each visual element of a representative example it was necessary to reproduce by means of deduction, reasoning from the known to the unknown, the pertinent knowledge and understanding of their makers.

Although it was not our purpose to quantify the physical forces present in the tracery networks that form the subject of our study (something that remains a theoretical possibility), one simply cannot truly understand their forms without giving due consideration to the jointing and assembly of the masonry elements of which they are made. As James (1973) clearly states, "the joints in the stonework are an important part of the design. They are never placed accidentally". In fact, Gothic rose tracery could justly be viewed as the result of the interplay between formal and constructional considerations.

Based on our analysis of representative historic examples, we put forward a number of hypotheses in regard to both the type and sequence of decisions faced by medieval designers. There are undoubtedly many ways one could go about representing the process of designing a rose window. However, if they are to be accurate, none of these ways should represent the process as consisting of a linear sequence of decisions, but rather of a nest of interrelated questions and answers. To model such a complex design process we chose to exploit a systemic approach, which expressly allows one to take into consideration not just the entirety of a designer's decisions, but, more importantly, also their mutual dependence (Le Moigne, 1990).

Such relationships of dependence were key elements in the modeling of the rose tracery networks, since they defined the logic of the whole design process. For example, we reason that the designer of a Gothic rose must have begun his composition with a circle of a certain size, that is, the circle delimiting the perimeter of the tracery network. Logically, he would then most likely have chosen the basic type of rose (oculus, multifoil or wheel). Subsequently, he would have decided how many foils or segments, as well as the type of decoration. These are just a few of the more important questions, posed by the system as imperatives, that form the basis of our model of the medieval design process and that we believe explain the various observable rose formulae.

The procedural model

Our effort was directed toward the establishment of parameterized descriptions of all possible outcome scenarios as determined by our analysis of representative examples such that a single model uniting all identified procedures would result. *Scheme*, a well-known functional programming language, permitted us to efficiently model the rose's inherent, productive compositional logic.

The establishment of the variables along with hypotheses concerning the productive compositional logic led to a first, trial version of the procedural model. The flexibility of this first model was, and still is, tested by substituting different values for the variables in order to see if it is always possible to describe each of the elements belonging to a given type. Our objective is to create procedures able to include the description of all the elements belonging to a given type. We intend to describe an ensemble of artefacts in the clearest and simplest way. In fact, our programming code is thereby optimized. As Springer and Friedman (1989) argue, "in programming, perhaps more than in other arts, less

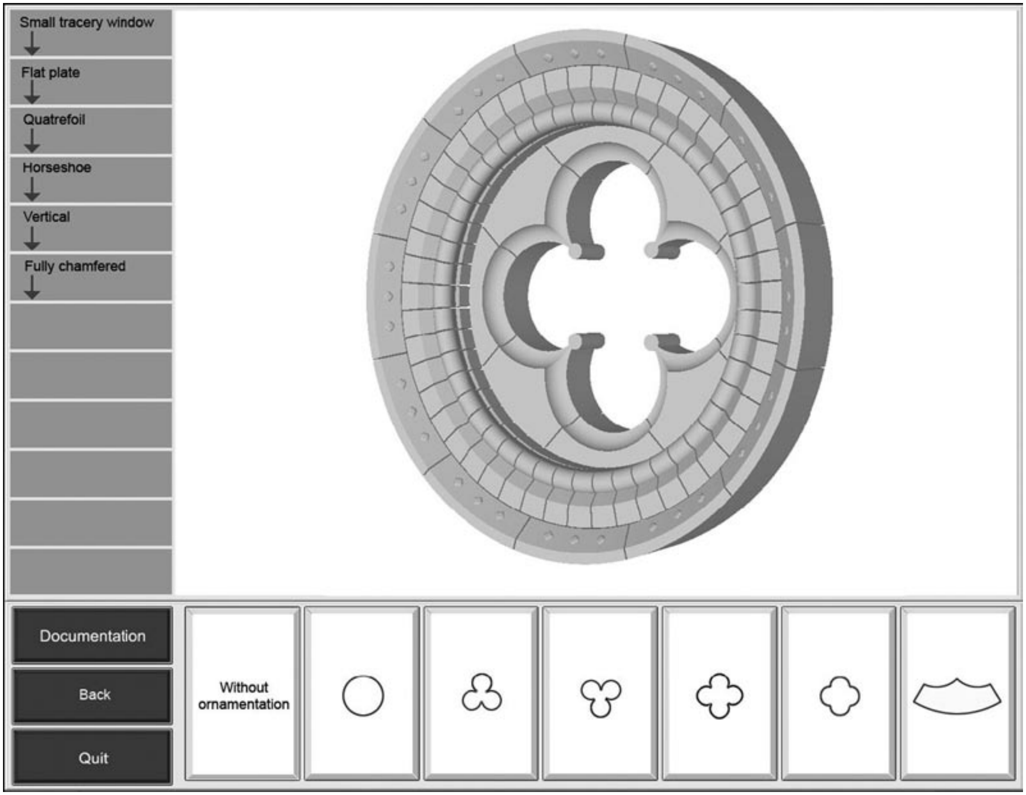

Figure 3
Procedural code.

is more. Simplicity is nowhere more practical than in programming, where the bane is complexity".

To illustrate more clearly how the compositional logic could be translated into concrete procedures, we reproduce below the code for the creation of the oculi, a procedure that permits multiple variants: roundel, chamfered oculus with or without a trim, and quatrefoil-shaped windows, each with different trim, moulding and jointing scheme (Figure 3).

The flexibility of programming code is such that, potentially, it can be constantly developed. We took advantage of this aspect of programming by initially taking into account only a relatively limited number of artefacts. As our study advanced, additional artefacts are successively incorporated into what is in reality a federative model. The fact that the type and number of variables given as arguments in the procedures can be altered easily is fundamental. Indeed, the successive addition of elements drawn from our historical study leads to the continuous testing and refinement of the developing typology. Since modeling is an iterative process, the great plasticity of the procedural model helps minimize any unnecessary expenditure of time and energy. As Lévy (1990) put it: "a model constitutes only a stage, a moment in an uninterrupted process of tinkering and intellectual reorganization".

Developing the software programme

Our software programme – at the time of writing, still under development – is adapted from the procedural model that constitutes its core. The programme is structured so as to "re-enact", so to speak, the series of choices and decisions that we believe once gave rise to Gothic rose window traceries. Thus, our software programme has been developed to generate representations of rose traceries by means of an unfolding, interrelated series of decisions. As a truly heuristic tool its function is twofold: first, to emulate every stage of the medieval rose window design process; and, second, to visually transpose the designer's intentions to a virtual design space. At each stage of the virtual design process, the screen presents various pictograms representing different design options and alternate pathways from which the user may choose. A choice is made by simply clicking on the pictogram (in reality, a button) repre-

```
(define rose
  (cond
    ((= type-oculus 0) (ocuNonExt))        ;oculus with no extrados
    ((= type-oculus 1) (if (= 1 trim-type) (ocuExt)        ;oculus with no trim
                           (shpUnion (ocuExt) (trim))))    ;else with trim

    ((= type-oculus 2) (cond    ;quatrefoil

                         ((= type-quatr 0)      ;Oulchy type
                         (cond ((= 0 moulding-type)  (quatr0 mould0)) ;with moulding 1
                               ((= 1 moulding-type)  (quatr0 mould1))  ;with moulding 2
                               ((= 2 moulding-type)  (quatr0 mould2)))) ;with moulding 3

                         ((= type- quatr 1)      ;St-Medor type
                        (cond ((= 0 moulding-type)  (quatr1 mould0))   ;with moulding 1
                              ((= 1 moulding-type)  (quatr1 mould1))   ;with moulding 2
                              ((= 2 moulding-type)  (quatr1 mould2)))) ;with moulding 3

                         ((= type-quatr 2)      ;Nanteuil type
                         (cond ((= 0 moulding-type) (quatr2 mould0)   ;with moulding 1
                               ((= 1 moulding-type) (quatr2 mould1))  ;with moulding 2
                                   ((= 2 frame-type)  (quadri2 fr2))))));with moulding 3
    ))
```

Figure 4
Software programme interface.

senting the desired option (Figure 4).

Since every choice is linked, earlier choices condition all subsequent ones, and the design space is conceived as an arboreal structure in which users can freely navigate – upward or downward, much as medieval designers must have done in pursuit and formulation of their design goals. The user's path into the arboreal sequence of the procedural model is represented on the upper left hand side of the interface. At any time during the design process the user can not only backtrack any of his actions, but also access documentation on Gothic rose windows, documentation designed to stimulate a deeper understanding of the subject and consequently aid him in designing traceries.

At the end of every branch of the structure, the code can be exported for visualization into a CAD programme, such as POV-Ray, AutoCAD or Catalyst. The user may generate an image, a 3D model or a prototype presenting a sum-visualization of choices made up to that point in the design process. The complementarity of the representations give users the possibility of apprehending complex 3D objects in virtual space, as well as the option of viewing various components from different angles so as to better grasp the consequences of their actions and the evolving morphology of their designs. Such a programme not only allows, but actively encourages, interaction at all moments of the design process, particularly during visualization and manipulation of the model in the virtual design space.

The programme can not only seize and recount every step of the design process; it also permits the modeling of typological variants. It is, in fact, possible for a user to design an authentic Gothic rose window irrespective of whether it corresponds to an actual historical example, or represents something that has never before seen the light of day. In either case, the rose will have been conceived according to the medieval know-how codified by the system.

We should like to emphasize that the software programme we have developed is not an automatic generator of rose traceries; the user is a true designer whose input is determinative at every stage of the design process. The software has not been designed to perform the mechanical application of a set of rules in accordance with a predetermined sequence, but rather to suggest available alternatives that help

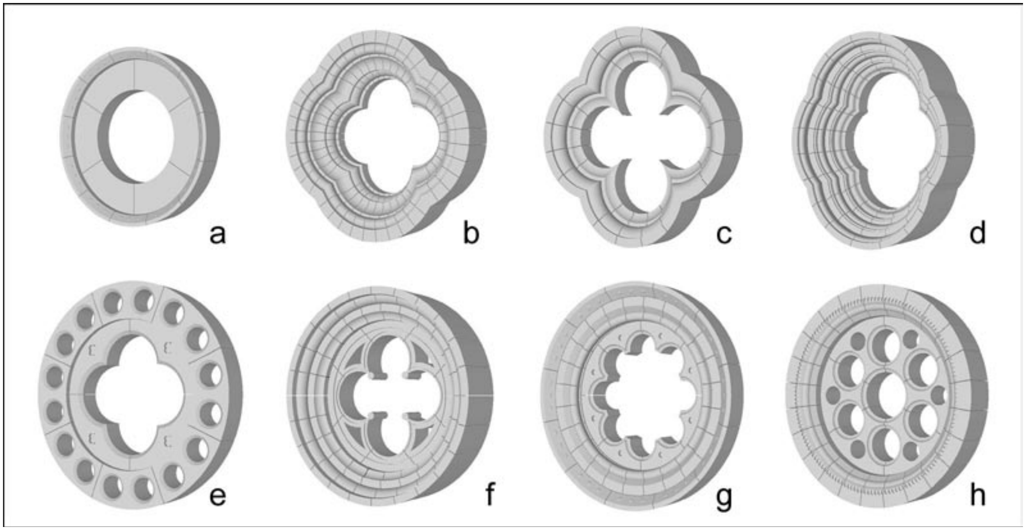

Figure 5
3D Models of rose windows: (a) oculus with a trim; (b, c, d) quatrefoil-shaped oculi (e) quatrefoil; (f) openwork quatrefoil; (g) eight-lobed oculus; and (h) plate tracery.

orient the user in his/her decision making within the established parameters of rose window design, and to provide timely visualizations that assist the user in understanding the design implications of his decisions. The users' critical reflection is always at the heart of the computer-assisted design process; the user should be able to "reflect-in-action" (Schön, 1983).

As our software program is still under development, the category of the colossal double wheel window (Chartres and Paris) awaits further definition. However, since members of this group employ the same logic that governs the smaller flat plate or wheel rose windows, their codes will be adapted from the latter and amplified. To date, our software programme has proven capable of generating a wide variety of rose tracery designs, ranging from the oculus to the openwork multifoil (Figure 5).

In addition to further development of the software programme itself, we should like eventually to undertake an evaluation of its usefulness in the development of the cognitive skills of art history and architecture students: to what extent do such programmes really help users to grasp a given artefact, in this instance the Gothic rose window, as a logical and articulate ensemble? We are inclined to believe that the use of a procedural model will favour the acquisition of knowledge. It is hoped that our completed software programme will help users to better understand medieval design by helping them to see it as a dynamic process comprised of many decisions meaningfully and consequentially interconnected. We believe that by organizing and presenting information in other forms than that of linear text, tables or figures, and in accord with a different logic, our software programme complements traditional ways of learning and will promote what Lévy (1990) has called "knowledge by simulation".

Conclusion

The procedural model we have developed has proved effective in modeling Gothic rose tracery designs in accord with traditional medieval know-how. While such know-how can never be replicated, our research shows that viable modeling strategies can be derived from it. By developing an approach based on the modeling of a given design process, we sought to achieve two primary objectives: first, the development of introductory software programmes, each based on a different pre-industrial architectural know-how (such as those of stairs and roof frames) and, second, the deployment of this software as a complement to more traditional pedagogical material in didactic contexts where art and architectural students could profit from a fuller approximation of the actual experience of the creation of architectural works of art.

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