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PACKING THE "CHINESE BOX"

A strategy to manage knowledge using architectural digital models

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Abstract. The architectural design activity has been transformed due to technological advances in building knowledge management. The research proposed is based on a three years long Ph.D. work on 3D models intended as graphical informative systems, layered according to the "*Chinese box*" paradigm and destined to professionals and researchers in architecture. The applied case study is referred to San Vitale's church in Ravenna, Italy: the monument was investigated through nested digital models produced by different computer programs. Passing through evolutionary steps identified as *synthesis*, *reduction* and *projection*, the resulting archive lowered its *Complication Ratio*, a numerical value inspired by fractal's auto-similarity, indicating a recursive modification in morphologies and contents. Models so conceived are qualified as progressive knowledge-based catalogues easily interchangeable and useful to understand how new or existing architectures work. As a result of this approach, representations obtained with surveys, historical chronicles, light analysis and acoustic simulations were composed following gradual refinements: technical data were collected running parallel to bibliographic research, enriching interactive virtual models sprung from a recursive criterion destined to increase the information enclosed into an undivided, lossless, digital archive.

Keywords. 3D modelling; virtual architecture; BIM; CAAD; information database.

1. Introduction

Practitioners and designers involved in building process use different tools and ways to represent projects and ideas: taking advantage of computer models is a consolidated praxis, however different offerings in terms of applications often leads to errors and omissions when transmitting data between software and operators. Likewise, when developing a new building or studying an existing one, different digital tools need various abstraction to perform analysis or evaluate constructive aspects.

The original idea, or its interpretation, may differ very much from conclusive representations, due to the huge data quantity included into the design process, where contemporary technologies could easily turn edifices into well organized digital archives, but according to different orderings or structures, still not unified and interoperable.

This paper introduces a methodological proposal, expected to make the most of information technology techniques, in order to collect data about architectural environments through a complex digital framework called “Chinese box”.

2. The architecture inside a “Chinese Box”

As Schmitt pointed out (2001), the building process could be generally interpreted as a not completely recursive top-down algorithm, in which the information from schematic design to fabrication, to management and archiving is continuously modified, from conceptual abstraction to a completely different built project, deeply transformed during its evolution.

To use a metaphor, it would be like all models produced during development stages would enter into tunnels, during which they were eventually subject to mutations entirely unrelated to previous or following steps: even if a tunnel passage do not really change what flows through it, it’s considered as a sort of black box where everything could happen without complete consciousness by operators.

Getting out of each tunnel, digital models used to formalize buildings’ representations and mostly realized with different software, could appear deeply amended if compared to their previous state: they are ready to take the next tunnel, being modified by other operators and getting a further development which will embed again new abstractions into them, while they should be logic emanations of the original idea instead (Figure 1).

Structural analysis programs for example use simplified architectural models or concept digital mock-ups: they introduce variations in order to reach a better performance evaluation, regardless of elements considered important for architectural finishes. The same happens for building energy simulation tools, fire prevention schemes and so forth. The outlined scenario, the tunnel metaphor, reveals how critical is to manage information all over the design process in real fabrication world, since practitioners tend to bend models to their specific aims frequently loosing *ex-ante* compatibility.

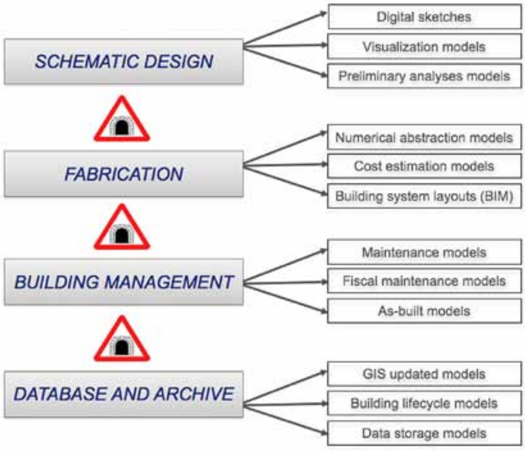

Figure 1. The “tunnel metaphor”: during the building process several applications produce different abstraction of the original idea, leading to not interoperable different models.

As Eastman et al (2008) have pointed out, this is considered a significant issue for cognitive representation. In reverse, the wide dataset management approach suggests how an integrated archive, if properly prepared to collect documents, could limit the loss of information conveyed through passages, overcoming tunnel’s criticalities and transmitting knowledge sequences as they really are, for new buildings and for existing ones.

This is the way to go, creating multi-discipline cognitive catalogues which establish an ordering principle for complexity, hierarchically embedding drawings, pictures, calculations and analytical schemes into an unique global archive: this is the intimate essence of a “Chinese box”.

Even changing the level of detail, knowledge previously acquired remains the same, gradually enclosed in different boxes one inside the other but similar in structure; a “Chinese box” model is a digital collector designed for building actors, promoting a representation of reality from different points of view, as hoped Colorni (2000), most likely moving through *interaction information workspaces* as intended by Liston et al (2001).

According to existing literature, such a comprehensive archiving method does still not exist in architecture, since B.I.M., *Building Information Models*, or C.A.A.D., *Computer Aided Architectural Design* software, can’t fully cover each aspect of cultural design process.

For example, a B.I.M. is too technical to transmit a concept, while a digital sketching program is too simple to produce analytical models to study the building’s performance on its own; probably they can’t even share properly abstraction of the same idea without compromising it.

Furthermore, existing tools for locating building products and assembly models (also known as B.E.M., *Building Element Models*) are still not ready to manage semantic structures, due to compatibility issues of multiple authoring tools. On the contrary, the "Chinese box" paradigm, as intended in this work, is first of all a recursive criterion destined to increase the information level enclosed into an undivided, lossless, digital computer model, making broad room for knowledge representation: results of every software abstraction are collected and made available to everyone in every moment (Figure 2), independently from computer programs used.

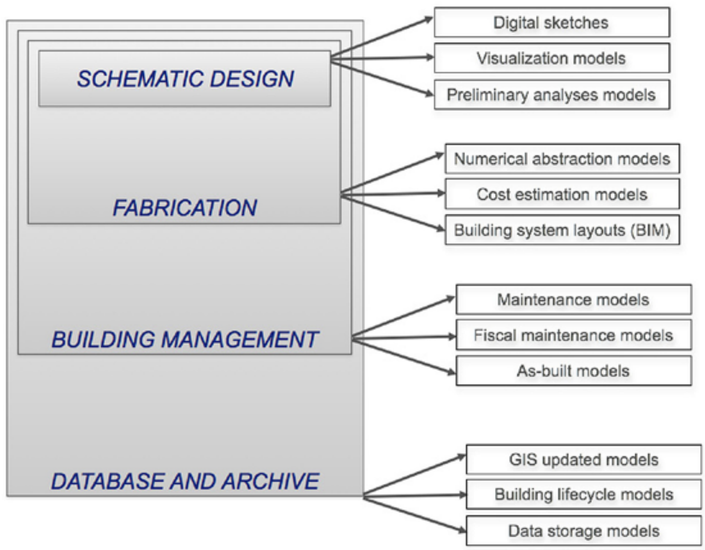

Figure 2. The "Chinese box paradigm": a recursive criterion destined to increase the information level enclosed into an undivided, lossless, digital computer model.

3. The auto-similar nature of a "Chinese box"

This study was influenced by Lindenmayer's works on relationships present in plants morphology, where the main structure is completed step by step while growing. Digital models realized to investigate Basilica of San Vitale for example, a following described case study, recursively followed this process stacking up subsequent data acquisition during three distinct phases: *synthesis, reduction* and *projection*.

Synthesis is expression of how information can be collected and ideally formalized into computer models, where geometry can be reconstructed for homology in virtual space, gathering heterogeneous data including pictures, sketches, or tables from surveys: it’s the modelling step, referred to morphologies and relations.

Reduction is mainly an oversimplification of the geometric and cognitive model produced, in order to control it in computer memory during analytical calculations. It’s a sort of abstraction aimed to perform validations of elements defined during synthesis: an architectural model topologically simplified to allow numerical analysis or energy metering for example, is *reduced*.

Interoperability between analytical tools is the core of this step: I.F.C. format, a way to catalogue building component according to their properties and functions, proved to be the best method to share data between applications without severe corruption.

Finally, with the *projection*, the informative model is presented to final users (architects, engineers, contractors, fabricators, customers) through the medium of technical drawings, visual renderings, performance charts overlapped to digital geometry and so forth. This is, briefly, the display of the design process results.

In a “Chinese box” these operations are cyclically performed so that richer models ease several uses, since they includes materials for a wide number of possible further abstractions. The three-staged scheme is iterative, fostered by several point of view of actors involved in building process: they are in some way influenced by their specific environment, which is surely constantly adapting and changing as Clancey (1997) points out with his *situated cognition*, but following methodological paths in a cyclical way.
This attitude recalls the Sierpinski’s triangle geometry, a fractal result of figures recursively repeated. Similarly, beginning from conceptual modelling, every time a significant development in synthesis, reduction or projection is achieved, a progressive complication is added (Figure 3).

In this way the “Chinese box” model evolves, relating its changing to a constant value similar to Hausdorff formulation for Sierpinski’s triangle *fractal dimension*, expressed in a specific format called R_C, *Complication Ratio*, obtained from empirical tests in order to evaluate the complexity of a digital model and written as:

$$R_C = \frac{x}{n} \times \frac{\log(3)}{\log(2)} \tag{1}$$

where x is a progress indicator for synthesis, reduction or projection while n represents subsequent development steps.

The Complication Ratio is a number, which consider several aspect of growing such as time to gain data, purposes for whom models have been imagined, level of detail embedded and so on (Figure 4).

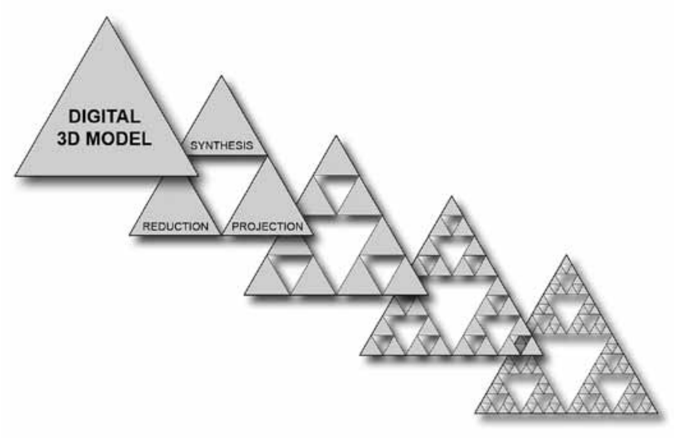

Figure 3. The "Chinese box" digital paradigm recalls the fractal auto-similarity, well presented by the Sierpinski's triangle: evolving stages of synthesis, reduction and projection can be imagined as self-repeating steps, adding complication to the whole model.

Although it's very difficult to quantify variables like these, due to heterogeneity of elements which can be inserted into boxes, they can be useful to determine the model dimension. Quoting Mandelbrot (1982) studies on fractal mathematics, the recursive "Chinese box" approach could be nearly similar to a "*fragmented geometric shape that can be split into parts, each of which is (at least approximately) a reduced-size copy of the whole*".

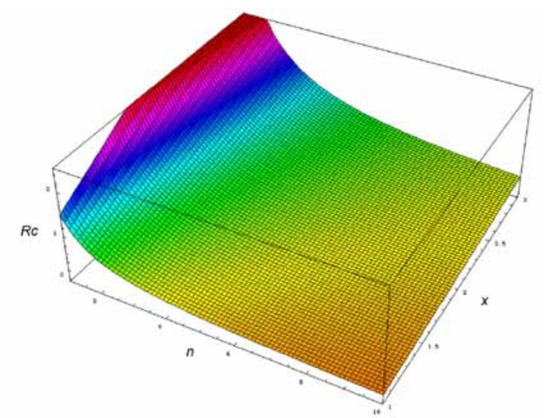

Figure 4. Complication Ratio tends to zero as the digital model evolves.

Without deepening furthermore the R_C expression, not the main subject of this paper, a descending Complication Ratio indicates an increasing level of development allowing extensive possibilities; it decreases quickly in the early stages of integration and becomes stable later, tending to a gradual asymptotic limit.

4. San Vitale’s Basilica case study

As previously claimed, the closer existing technology to “Chinese box” modelling is surely B.I.M.; however it doesn’t address issues deriving from existing buildings representation, since it’s been mainly developed as a tool for fabrication *ex-novo*. The “Chinese box” on the contrary, was tested in a Ph.D. research on a well-known example of monumental architecture, in order to establish if evolutionary parameter isolated would be effective even surveying a built historic environment.

San Vitale, the elected site, is an Italian church in Ravenna and one of the most important examples of early Christian Byzantine architecture in Western Europe. A photogrammetric survey was realized together with natural lighting evaluation inside the church (Figure 5), while some archaeoacoustic analysis were carried out through derived models, as presented and documented by Knight (2010).

Figure 5. The increasing knowledge about San Vitale was embedded into 3D models, gradually evolving in synthesis, reduction and projection as well, with lower and lower R_C values.

Through several steps and various applications communicating together (Table 1), knowledge about San Vitale was embedded into a growing model, gradually changing its content through synthesis, reduction and projection as well. Presentation of final achievements, the most interesting aspect from the technical point of view, is the clearest expression of what a "Chinese box" is: exploring a simplified 3D digital model (in form of a nested 3D PDF file), it's possible to focus attention on details which can be delved linking results obtained from previous steps (Figure 6).

Table 1. Steps to collect results from various tools into San Vitale's integrated model.

Phase	**Description**	**Synthesis change**	**Reduction change**	**Projection change**	**Software used**
Step no. 1	San Vitale's sketchy modelling aimed to prepare a survey and scheduling geometrical data retrieving.	1 (3D model aimed to understand volumes)	1 (geometrical CAD simplification)	1 (paper printings to be used during survey)	Google SketchUp, Autodesk AutoCAD
Step no. 2	Increasing of the level of detail according to information acquired during surveys.	1 (geometry much more detailed after survey)	1 (CAD integrated by photogrammetry)	0 (no variations)	Autodesk AutoCAD, EoS Photomodeler Scanner
Step no. 3	Inclusion of QTVR digital photographic panoramas into the main geometrical model.	0 (no variations)	1 (Model conversion in PDF format)	1 (Model preparation to be explored)	VR Worx, Adobe Acrobat Extended
Step no. 4	Geometrical draping of raster textures in 3D models, to characterize materials and mosaics.	0 (no variations)	1 (Model conversion in texturable primitives)	1 (Digital draping aimed to rendering and movies)	Autodesk Maya
Step no. 5	Oversimplification of 3D models to obtain abstractions aimed to acoustic and FEM lighting simulations.	0 (no variations)	1 (Abstraction for numerical analysis)	1 (Layering of results onto geometry)	Autodesk Ecotect Analysis, Ramsete
Step no. 6	Preparation of a digital integrated archive accessible through several devices (i.e. using PDF 3D format).	0 (no variations)	0 (no variations)	1 (Model presentation via Internet)	Adobe Acrobat, Autodesk Revit

For example, from the main model of San Vitale (which could be even presented on web), photographic VR panoramas from the survey campaign, light analysis of sun rays on interior mosaics or a simulation movie of how could appear the church in VIth century, can be all easily consulted, together with a link to analytical stored files. Patently, those elements were gathered during different phases and managed by different software.
Then procedures followed, historical notes, descriptive papers were collected into the "Chinese box" in form of database, with tables stored inside 3D PDF archives or linked to the models' components.

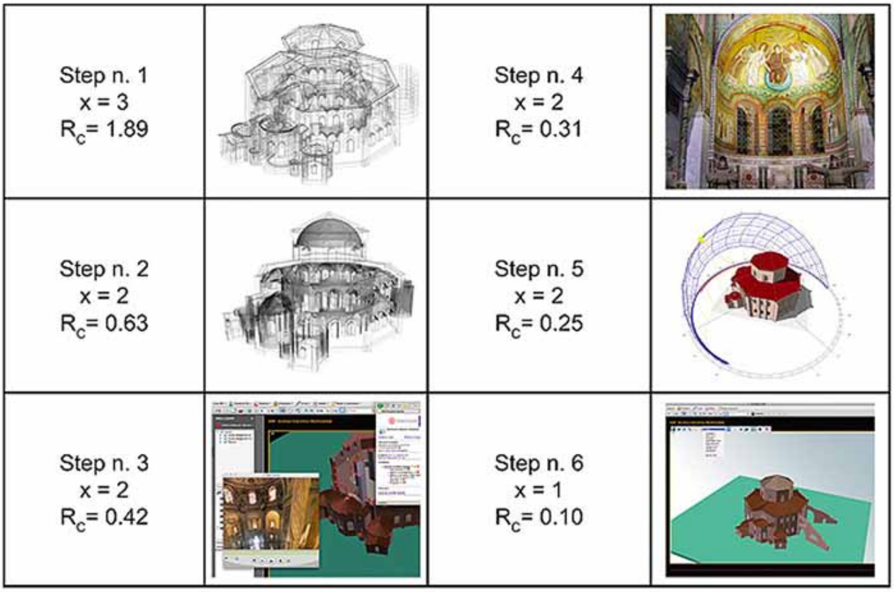

Figure 6. The San Vitale "Chinese box" model: the R_C value decrease as knowledge elements are added to the archive. This behaviour was confirmed by several tests, referring to new and existing buildings during survey or fabrication. The x indicator expresses how many variables (synthesis, reduction or projection) change their contribution during selected step.

5. Conclusions

Construction is a collaborative endeavour, a complex process in which concurrent goals are to be fulfilled, as Gero and Kulinski wrote (2000). The "Chinese box" is a tool aimed to arrange in concert and destined to architects, engineers, researcher, contractors, fabricators and so on, just to make knowledge sharing easier. It's not a computer program, it's a human activity which involves an inevitable process of change in methods applied to architectural-related disciplines.

In years to come, the conscious use of existing tools will contribute to the spread of high-profile building components, generating a great flexibility and variety in methods and types of construction. Optimistically, this process will produce less building documents, containing less errors, avoiding time wasting and allowing fabricators to arrange late changes, reaching higher productivity.

On the other hand, project's standardization due to digital tools is a danger to keep in mind: for this reason, high technologies and proprietary software should be introduced into the design chain only in specific points, favouring the choice of interoperable algorithm and devices. This is the crucial point which promotes the "Chinese box" modelling as an alternative to pure B.I.M., as it can't successfully integrate all the cultural work flows in a coherent manner, allowing actors involved to analyze in a deep way architecture during the whole building process.

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