Beyond modelling: Avant-garde Computer Techniques in Residential Buildings

Más allá del modelado: la vanguardia de técnicas informáticas en edificios residenciales

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Resumen:

Si el resultado de innovaciones informáticas puede ser interpretado como una incipiente “diferencia“ en la calidad del espacio construido, entonces para entender que futuras aplicaciones pueden tener en arquitectura, debemos estudiar que técnicas hay actualmente disponibles para el diseño de formas y espacios (DeLuca and Nardini, 2002).
Recientemente el llamado método paramétrico, un método diseñado para encapsular múltiples diseños del mismo tipo en programas informáticos, esta siendo el centro de atención en el campo informático dentro de arquitectura. En este artículo, reflexionamos sobre el uso actual de los métodos paramétricos, usando como ejemplos proyectos que usan técnicas innovadoras y nuestros propios programas, para a continuación evaluar como estas innovaciones informáticas pueden ayudar a mejorar la calidad de los edificios residenciales.

Abstract:

If the result of computer innovations can be interpreted as an emerging “difference” in the quality of constructed space, then in order to truly understand what future applications may be regarding architecture at present, we should look at what advanced functions are available in the process of designing forms and space (DeLuca and Nardini, 2002).
Recently the so called parametric approach, a technique for describing a large class of designs with a small description in programming code, has become a focus of attention in architectural computing. In this paper, we reflect on the current use of parametric tools using real case studies as well as our own proof of concept parametric programmes and report on how the avant-garde computer techniques may help to increase the quality of residential building.

1 INTRODUCTION

The spread of new technical possibilities over the last thirty years offered by the use of computers in design has opened the way for new advances, which would have been unrealisable without the help of electronic tools. If the result of computer innovations can be interpreted as an emerging “difference” in the quality of constructed space, then in order to truly understand future architectural applications, we should look at what advanced functions are available in the process of designing forms and space. The newest CAD tools share the one main characteristic of joining typical architectural techniques of representation (i.e. CAD modelling techniques) with interactive control technologies (i.e. artificial intelligence techniques) to aid in the design of forms and spaces.

The most innovative current platforms performing complex parametric functions tend to eliminate the need to choose whether to use traditional technologies (2D-3D) or different methods. Instead they integrate Reverse Engineering (beginning with the object and transforming it into a digital format via 3D scanning) and design programmes, or hardware and software engineering with product development tools (i.e. rapid prototyping). This flexibility helps maintain traditional tools alongside innovative tools.

In this paper, we reflect on the current use of parametric tools using real case studies as well as our own proof of concept parametric programmes and report on how the avant-garde computer techniques may help to increase the quality of residential building. Hence, we first establish the key factors of quality in building using the Design Quality Indicators (DQI) as the conceptual framework, before discussing the Digital Morphogenesis design process with particular emphasis on parametric methods. We then consider these concepts in relation to real case studies, concluding with an appraisal of the impact of avant-garde computing techniques upon the quality of residential building.

2 DESIGN QUALITY

In order to evaluate the possible effects of avant-garde computer techniques on the quality of residential buildings, it is first necessary to establish a valid framework against which to measure quality. The establishment of a definition of the aspects which impact on quality is therefore required. As such we will consider the debate over notions of quality in the construction industry in the United Kingdom, and the methods of evaluation which have emerged from this debate.

2.1 Architectural quality

Although ‘quality in building’ is generally recognised as being a positive thing (OGC, 2004), exactly what ‘quality’ means is hard to define. The size and fragmented nature of the construction industry mean that the term quality can be considered variously in terms of design, production, delivery and usage. Concepts of quality can also alter depending on one’s viewpoint. The differing views and values of the many stakeholders in the industry; clients, design team members, contractors, and most importantly users must all be taken into account. As a result, concerns for quality in building may variously include notions of style, appearance, functionality, whole-life-value, maintenance, flexibility, management, health & safety, sustainability, environmental impact, ease of construction, efficiency of spaces, place-making, access for all, outlook, ergonomics, colour, texture, light, energy efficiency, internal environment, and future-proofing.

In this paper we are arguing that avant-garde computer techniques may aid to increase the quality of residential building. As discussed above, the concept of quality of design is difficult to quantify as such and, therefore, like in many practical problems, the conditions of a well-defined problem are not met. In other words, if the concept of quality of design were a well-defined problem it could, in turn, be mapped onto the digital environment using existing or new ways of formalising knowledge. In general, computer aided architectural design techniques are oriented towards the well-defined rather the ill-defined, aspects of design but advances in Artificial Intelligence (AI) research are resulting in the implementation of systems capable of responding effectively to increasingly ill-defined problem situations. Hence and in order to qualitatively interpret whether the result of computer innovations can be seen as an emerging “difference” in the quality of constructed space, we are mapping a conceptual framework developed for describing aspects of design quality onto the state-of-the-art digital environments used by the most prestigious architectural and engineering firms in the United Kingdom. This conceptual was developed by the Steering Group as a part of the following Construction Industry Council (CIC) project: Design Quality Indicators (DQIs) and it is explained in the next section.

2.2 Design Quality Indicators (DQIs)

In the United Kingdom in the last half-century general design quality, particularly in residential buildings, has been less than excellent. The widespread failure of the industry to deliver quality buildings in recent decades, in terms both of architecture and construction, led to an attempt to try to improve quality in the production of buildings. Drivers for change were The Egan Report "*Rethinking Construction*" (1998); The Royal Institute of British Architects (RIBA) supporting a move towards the valuing and recognition of design quality as a way in which the marginalisation of architects within the industry might be reversed; and the recognition of design quality as a political issue. This pressure led the Construction Industry Council (CIC), an organisation which represents the interests of professional bodies in the UK construction industry, to set up a team to develop the Design Quality Indicator (DQI).

The Design Quality Indicator provides a useful framework against which design quality in buildings can be assessed, as it covers notions of quality from all participants and in all relevant fields. The starting point for the DQI method of measuring design quality are the general fields of 'Build Quality', 'Functionality' and 'Impact', each related to Vitruvian principles. However, a more complex framework underpins the DQI system (Gann et al, 2003). The aspects of the framework are generally related to overall concepts of 'Build Quality', 'Functionality' and 'Impact', and are the real underlying issues which determine the quality of building. The aspects shown in Tables 1 and 2 provide the basis for our investigation of the impact of avant-garde computer modelling techniques on the quality of residential buildings.

3 DIGITAL MORPHOGENESIS

In contemporary architectural design, digital media is increasingly being used not as a representational tool for visualisation but as a generative tool for the derivation of form and its transformation –the digital morphogenesis (Kolarevic, 2000). In a radical departure from

Design Aspect	Description
Siting / Orientation	The positioning and orientation of the building within its site
Space Allowance	The amount of space allocated to activities, relative to the type of activity that will occur in that space
Circulation Efficiency	The efficiency with which space is allocated for circulation relative to other uses within the building
Clarity of Expression	The extent to which the building is an eloquent expression of the concepts behind the design
Health and Safety	The extent to which the design promotes Health and Safety in its fabrication and construction
Structural Efficiency and Elegance	The efficiency of the structure of the building and the consequent elegance of the structural expression
Buildability	How easy the building is to construct
Durability	The durability of the materials used in the building

Table 1: Aspects Determining Quality of Building

Design Aspect	Description
Finishes	The selection and quality of material finishes in the building
Natural Light	The provision of natural light where appropriate
Vision	The availability of views out of the building, where appropriate
External Form	The impact of the external form of the building
Spatial Qualities	The experiential quality of the spaces within the building
Civic Contribution	The contribution of the building to its built surroundings
Valuing the User	The level to which the design of the building values the user and reflects their needs.
Innovation	The extent to which the design of the building is innovative, in terms of any of the other aspects

Table 2: Aspects Determining Quality of Building

centuries-old traditions and norms of architectural design, digitally-generated forms are not designed or drawn as the conventional understanding of these terms would have it, but they are calculated by the selected generative computational method. In other words, a generative design is a design methodology that differs from other approaches in that during the design process the designer does not interact with materials and products in a direct ("hands-on") way but via a generative system: we interact with the process to generate a shape (the interaction is with the mechanism not with the shape). Figures 1 and 2 try to illustrate this graphically.

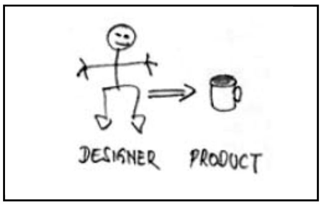

Figure 1. Traditional Design Methodology (Fischer & Herr, 1998)

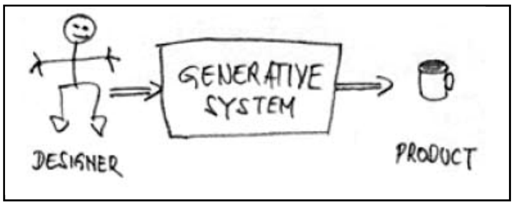

Figure 2. Generative design as a design methodology (Fischer & Herr, 1998)

A generative system is a set-up based on abstract definitions of possible design variations capable of displaying or producing design products (or elements of design products). There is in principle no reason to restrict this approach to the application of digital tools. Fully analogue systems are possible too. For instance, a famous example of practical use of an analogue generative system in architectural design occurred in the work of the Spanish architect Antonio Gaudi (Mitchell, W. 1977). In design of the church of the Sagrada Familia and Guell Chapel in Barcelona, Gaudi employed a flexible, suspended wire frame covered in cloth and hung with weights (see figure 3). As the wires and weights were manipulated, the wire frame took up different forms, determined by the laws of statics governing suspension structures. The tension wires in the suspended frame were taken to represent the compression members in a vaulting system so that, if inverted, the form of the frame would represent an appropriate form for the vaulting.

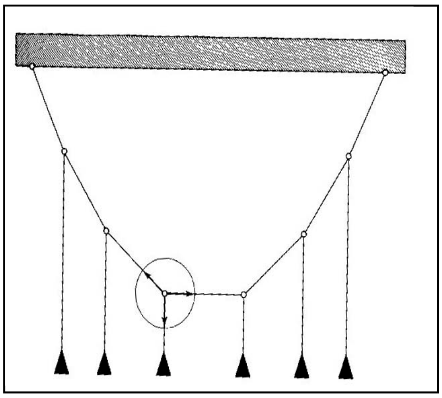
Figure 3. Gaudi's analogue generative system (Mitchell, 1977)

As stated above, though generative design is not restricted to the application of particular types of tools, digital computers have turned out to be especially appropriate for the following reasons (Fisher and Herr, 1998): first, to generate design implies a somewhat industrial approach to production insofar as efficient automation is required to output large quantities of solutions. In contrast to industrial manufacturing however, generative design leaves the monotony of production up to the computer and at the same time overcomes and avoids the monotony of products. Some scholars argue that this idea has triggered a paradigm shift in designing and manufacturing architecture: mass-customisation. We will review this later on in the paper. Another important reason why digital environments are particularly well-suited is that a significant part of generative design labour comprises permutation of design elements and attributes, which is most easily accomplished by means of symbolic computation. Finally, this symbolic representation that is inherent to computer-aided design (CAD) also seamlessly integrates elements of design simulation. Generative design solutions come into existence in form of digital representations, allowing early evaluations before their actual (i.e. physical) modelling, production or application. In this respect, generative design differs vitally from its natural inspiration in that experiments, generates and extinguishes designs in the most blind and unscrupulous ways.

Today, parametric design, relational modelling, genetic algorithms, shape grammars, shape evolution, cellular automaton are important and very common keywords in international discourses in CA(A)D –Computer Aided Design in Architecture- but due to their relative novelty and complexity, not all of these approaches are part of main stream architectural design as yet. In the next subsection we review the principles behind parametric design: the main approach used in commercial projects and illustrate their application with appropriate examples

3.1 Parametric and relational modelling

Originally relational modelling was conceived as an extension to parametric design in order to overcome its limitations. However, nowadays, the distinction between the two has been blurred due to the commercial value of the word parametric. That is, commercial software manufacturers have started to incorporate relational modelling principles to their original parametric design environments but, instead of adopting the original academic terminology coined by Mark Gross (Gross, 1990) they have opted for maintaining the word parametric to avoid confusing amongst the non-specialist audience. In this paper, on the other hand, we have selected to keep the distinction for the sake of our academic argument: avant-garde computer techniques may help to increase the quality of residential building.

Parametrics can provide for a powerful conception of architectural form by describing a range of possibilities, replacing in the process stable with variable, singularity with multiplicity. Using parametrics, a designer could create an infinite number of similar objects, geometric manifestations of a previously articulated schema of variable dimensional, relational or operative dependencies. When those variables are assigned specific values, particular instances are created from a potentially infinite range of possibilities.

We have created several examples of how parametrics could be used in architectural design. For instance, we have developed a window pattern generator which could be used by designers to quickly generate many options for different façade designs. Figure 4 illustrates this principle: on the right, a computer generated pattern for a high rise building and, on the left, a possible application of that pattern. Similarly, we have also developed a parametric glazing system (see Figure 5) using ArchiCAD GDL scripting language. It is intended to create a fully operable 3D GDL object that will not only provide a visual aid for the imagistic goals of digital design but will also aid later in the manufacture of the designed item allowing for an improved interaction between design and manufacture and therefore improving the cohesiveness of the built form. The parametric programme in this case facilitates these iterations through an easy generation of instances of the same object.

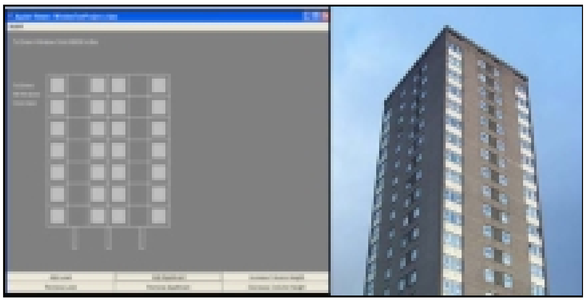

Figure 4. Window Pattern Generator (left) and patterns in a real facade

Figure 5. Parametric Object (left) and glazing system in real building

In parametric CAD systems, design features are identified and keyed to a number of input variables. Changes in the input values result in variations of the basic design. Based on conventional software technologies, parametric design has been successfully applied in many design domains including architecture and is supported by several commercial CAD packages. A weakness of parametric techniques is that need to predetermine which properties are input parameters to be varied and which are to be derived.

Relational modelling is a simple and powerful extension of parametric design that overcomes this weakness (Gross, 1990). By viewing relations as reversible rather than one-way, any set of properties can be selected as input parameters. For example, a relational model that calculates the shadow length of a given building can also be used to calculate the building height given a desired shadow length. In exercising a relational model the designer is not limited to a pre-selected set of input variables but can explore and experiment freely with changes in all parts of the model.

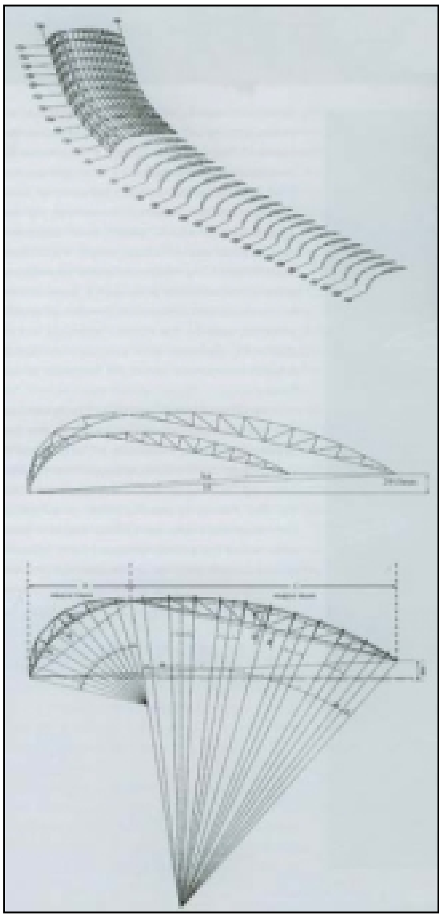

Figure 6. *International Terminal,* Waterloo Station, 1993, London, UK. Architect: Nicholas Grimshaw & Partners. (Kolarevic, 2003)

The Internal Terminal at Waterloo offers a clear demonstration of conceptual and developmental benefits afforded by the relational modelling approach to design. The building is essentially a 400m long glass-clad train shed, with a “tapering” span that gradually shrinks from 50m to 35m. Its narrow, sinuous plan is determined by the track layout and the difficult geometry of the site, which is the main source of the project’s complexity and which gives such potency and significance to Grimshaw’s design, especially its spectacular roof structure. The roof structure consists of a series of 36 dimensionally different but identically configured three-pin bowstring arches. Because of the asymmetrical geometry of the platforms, the arches rise steeply on one side with a shallower incline over the platforms on the other side. Each arch is different as the width of the roof changes along the tracks.

Instead of modelling each arch separately, a generic relational model was created based on the underlying design rules in which the size of the span and the curvature of individual arches were related. By assigning different values to the span Parameter, 36 dimensionally different yet topologically identical, arches were computed and inserted in the overall geometric model. The relational model could be extended from the structural description of arches to the elements that connect them, the corresponding cladding elements, i.e. to the entire building form. Thus, a highly complex hierarchy of interdependencies could be relationally modelled, allowing iterative refinement, i.e. the dimensional fine-tuning of the project in all stages of its development, from conceptual design to construction (see Figure 6) (Kolarevic, 2003).

As shown by this project, parametrics, in the wider sense of the word, are particularly useful for modelling the geometry of complex building forms. We are currently extending relational modelling approaches to the realm of 3D real-time environments in which designers can freely navigate and interact in real-time with the objects displayed in the configuration (Calderon et al, 2003).

Finally, the development of parametric and relational geometry in CAD systems has been taking a step further by creating a direct link between what can be conceived and what can be constructed. Building projects today are not only born out digitally, but they are also realised digitally through “file-to-factory” processes of computer numerically controlled (CNC) fabrication technologies. In order to achieve this, CAD systems are expended with software macros which can, for instance, generate a glazing solution, lay out the glazing panels, schedule all areas of the façade, and listing every panel coordinates (Whitehead, 2003) However, there is a step prior to the “file-to-factory” process: design rationalisation. This means that the whole building has to be reanalyzed as a set of construction components. This is a complex process which is outside the scope of this paper.

4 CASE STUDIES

4.1 Chesa Future

The Chesa Futura (Figure 7) is a residential building located in the Swiss skiing resort of St. Moritz. It was designed by architects Foster & Partners and engineers Arup for a private client between 2000 and 2004.

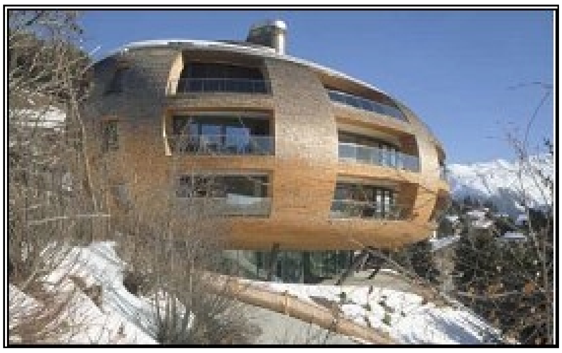

Figure 7. External View of Chesa Futura (Glover & Koppitz, 2005, pp11)

Foster and Partners used advanced parametric modelling techniques to enable them to rationalise the form and to realise its construction. The programs were specifically developed for the project by the Specialist Modelling Group (SMG), an in-house consultancy at the firm. Initial design sketches were formalised into a parametric model, which allowed any changes made to the form to be tracked. The model enabled design-team members from three countries to exchange ideas.
The digital model was used at all stages of the project, from planning to detail. It was used to produce accurate models of the design and eventually to drive Computer-Numerically-Controlled (CNC) machines in the fabrication process.

Assessment of Quality of Building
In the following paragraphs we assess the quality of the building against the aspects of quality of building defined in Tables 1 and 2 (see Section 2.2).
External Form
The idea to use a curved form resulted from the constraints of the site. However, without the use of parametric technologies to rationalise the form, the building would have had to be orthogonal. Had this still been raised above the ground the external expression would have been clumsy and bulky. The use of parametric computing techniques meant that the unusual and expressive rounded form of the building could be realised. As such, designing the building in the digital environment has significantly improved the architectural ‘impact’ of the project. See Figure 8 for a comparison between the rounded form and a less innovative option.

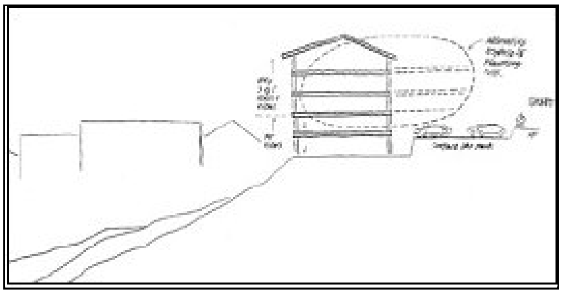

Figure 8. Comparison between rounded and orthogonal forms (Fantoni, 2002, pp4)

Orientation / Natural Light / Views

The orientation of the building, particularly in reference to the prevailing climatic conditions, depends upon its form being modified to maximise the amount of façade available on the south side. This was achieved by manipulating of the form parametrically in the digital environment. This allowed the designers to alter the overall form of the building to maximise the amount of façade that could benefit from solar gain, whilst avoiding the changes having a negative impact on other aspects of the design. Without this methodology the amount of natural light available within the apartments would have been greatly reduced, or have come at the expense of usable floor space. The curved geometry of the building also makes possible the exploitation of balconies to the south side to maximise views from the apartments (see Figure 9).

Figure 9. View from balcony (Glover & Koppitz, 2005, pp13)

Space Allowance

The rounded form means that the relationship between the positions of external walls and the available floor area is exaggerated. This makes changes in floor areas and heights resulting from the manipulation of the form crucially important. For example, *“a 2-degree rotation of the plan resulted in a 50 sq.m. loss of floor area…”* (Fantoni, 2002, pp9). The quick propagation of multiple designs in the parametric model meant that many design options could be evaluated (Figure 10). Keeping track of changes to variables ensured that internal floor area could be maximised. Thus the use of digital tools had a direct influence on the space allowance of each apartment and consequently the quality of the constructed space.

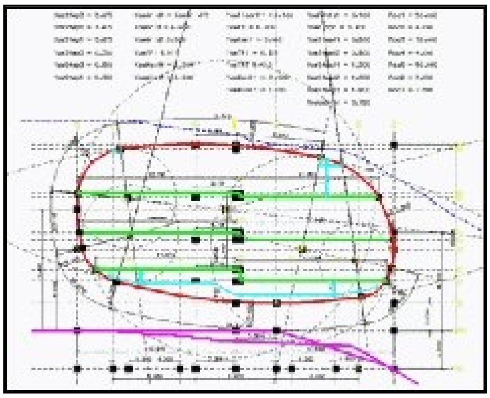

Figure 10. Parametric Model (Fantoni, 2002, pp9)

Structural elegance/efficiency

The structural design for the project was complex, requiring the co-ordination of multiple systems (Figure 11). In particular, the geometry of the timber structure was important to the overall structural stability, and was achieved using CNC cut glulaminated beams. The curved shapes of these beams were set out using the digital model of the project and the information then shared with the timber contractor. Without the use of the digital model, the curved form of the structure might not have been possible to achieve, and certainly not to such a high standard of pre-fabrication:

> *“An absolute tolerance of +/- 0.5mm was upheld throughout the manufacturing process, and +/-20mm for the completed structure.”* (Glover & Koppitz, 2005, pp13)

In addition to enabling the structural expression, the digital model was also the driver behind the precision of the final building. Such a high level of performance in terms of construction displays another aspect of the

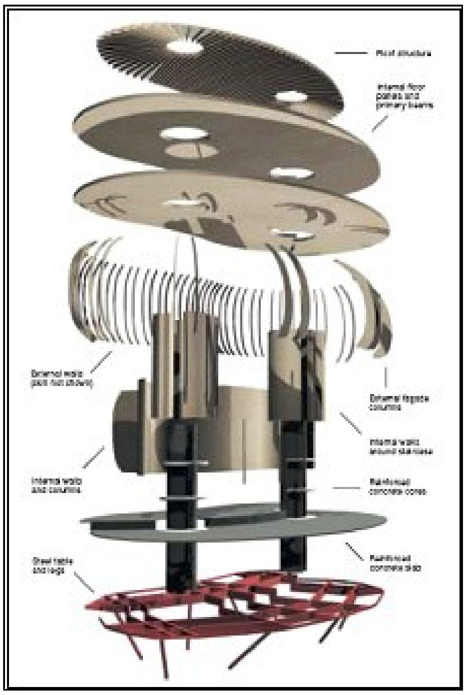

Figure 11. Exploded axonometric of structure (Glover & Koppitz, 2005, pp12)

quality of the building that was improved as a result of the use of advanced digital techniques.

Buildability

Figure 12. Pre-fabricated sections (Fantoni, 2002, pp5)

The general buildability of the building, an aspect of design quality particularly of interest to contractors, was not only enhanced but *enabled* by the use of the parametric digital model. We have already seen that both the form of the building in relation to the site and planning restrictions, and the structural expression were enabled by the use of these techniques. The buildability of this building depended on the ability of the designers to rationalise the curved form into manageable sections which could be fabricated (Figure 12). Using the digital model, the designers could produce drawings of any part of the building at any stage of the project. Buildability was further increased with software macros (small parametric programs similar to the window pattern generator already discussed) being used to calculate the arcs of the elements based on the parameters entered into the model. The digital model also allowed the design team to fix setting-out positions for the entire design prior to fabrication. Digital information was exported directly to machines for model-making and manufacture. As has already been mentioned, a high level of precision in pre-fabrication was achieved which increased the quality of the buildability of the scheme.

Finishes

Figure 13. Detail of External Finishes (Fantoni, 2002, pp11)

The digital model was also used to ensure the quality of the external finishes of the building. The design team chose to use larch shingles as the external cladding which were applied by hand to timber battens. The layout of these battens was crucial to the expression of the external finish, because they determined the layout of the shingles above. The positions of the battens were all calculated on the digital model and translate to a coursing diagram. This meant that the rows of shingles would be placed exactly where the designers wished (Figure 13). The use of the digital model thus facilitated an increase in the control and quality of the external finishes.

Thermal Comfort

The design of the building had to meet strict Swiss building standards as well as the client's expectations for high levels of internal comfort. The curved geometry of the building allowed larger openings to be provided to the south side than would otherwise have been possible. On the north side of the building the geometry creates a more enclosed façade, which is punctured only by small windows. Ultimately the rounded form allows more energy to be derived from solar gain than would otherwise be possible. The geometry enabled by the digital model is therefore vital in saving energy (and the client money) whilst maintaining a high level of thermal comfort for the occupants.

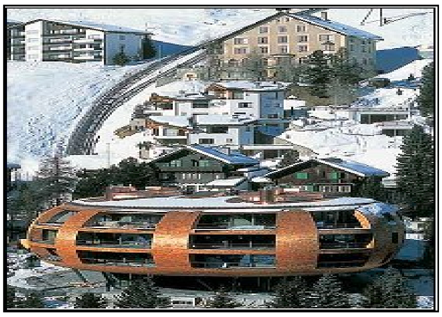

Figure 14. Chesa Futura and surrounding buildings. (From *"Schindelhaus auf Stelzen"*, 2003) Photo: Patrick Blarer

Innovation / Civic Contribution
The civic contribution of the building is one of impact and integration (Figure 14). The rounded geometry of this building is still a new phenomenon, particularly in residential buildings. Innovation, a key component of quality in buildings, was enabled by the new digital techniques deployed in the design of the Chesa Futura.

4.2 Bankside Paramorph

The Bankside Paramorph is a project for a rooftop apartment as an extension to an existing tower (Figure 15). The tower is located next to the Tate Modern in London, by the bank of the River Thames and opposite St Paul's Cathedral. The design for a penthouse apartment in this location is constrained by regulations relating to the maximum volume of the addition, laws governing its thermal properties, and the need for a lightweight and rapid means of construction. In addition the roof of the existing tower is stepped rather than flat.

Figure 15. Project Location: Bankside, London. Dritsas &Gunji, 2005

The designers are dECOi Architects, an interdisciplinary practice based in London and Paris who are interested in exploring the possibility of architecture within the new terrain of digital technologies and practices. They have tackled the project using parametrically variable computer modelling to maximise the quality of the building. This is in part an exploration of their concept of a 'paramorph', defined as *"the changing of a form while maintaining the form's properties."* (Whitehead, 2004)

Assessment of Quality of Building
In the following paragraphs we assess the quality of the building against the aspects of quality of building defined in Tables 1 and 2 (see Section 2.2).

External Form / Spatial Enclosure
The proposed external form of the building is complex, spiralling and tessellated. In a similar way to the Chesa Futura, the form is the result of the limitations imposed on the project. The spiral form is derived from the stepped shape of the tower and a maximum enclosure of space. This concept form was modelled basically in 3DStudio Max and this used as the basis for a parametrically variable model of the scheme (Figure 16). This model allowed different variations on the initial form to be considered whilst ensuring that restrictions on volume, height, and overhang of the design were not exceeded. The increased complexity of the external form in comparison with that of the Chesa Futura (Figure 17) demonstrates the advances in computational modelling in the intervening years. We can see that the use of digital technologies can lead to an

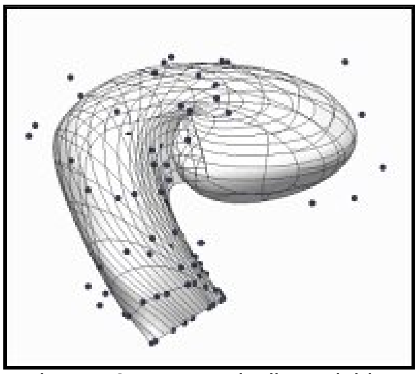

Figure 16. Parametrically Variable Model. Dritsas &Gunji, 2005

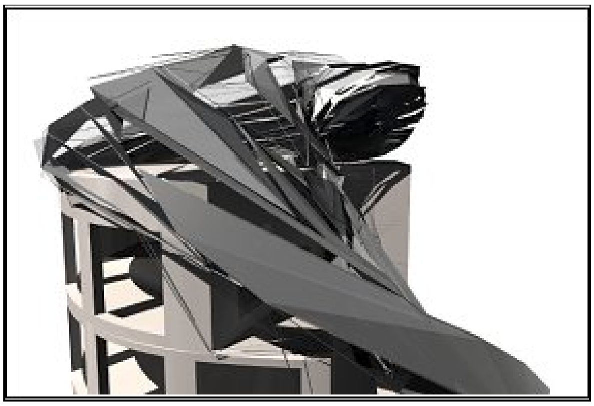

Figure 17. External Form. Dritsas & Gunji, 2005

improvement in the design of external forms a key aspect of quality.

Vision (Views) and Thermal Performance

The provision of views out of the apartment in all directions was a requirement of the brief. However, thermal performance regulations restricted the maximum area of glazing on the façade to 45% of the total. We have already seen that vision and thermal performance are both important aspects in the assessment of quality in buildings. The provision of views in all directions whilst keeping to glazing restrictions is a challenge, especially when considering a form of this complexity. By including the restriction on glazing as a parameter in the digital building model, the designers were able to ensure vision without adversely affecting thermal performance. The model also allowed integration of the glazing positions with the structural system, ensuring that no clashes would occur. The interaction of these parameters has contributed not only to the quality of vision and thermal performance, but also to the impact of the building through the resulting striations in the external fabric (Figure 18). This is a further progression from the more conventional layout of glazing in the Chesa Futura.

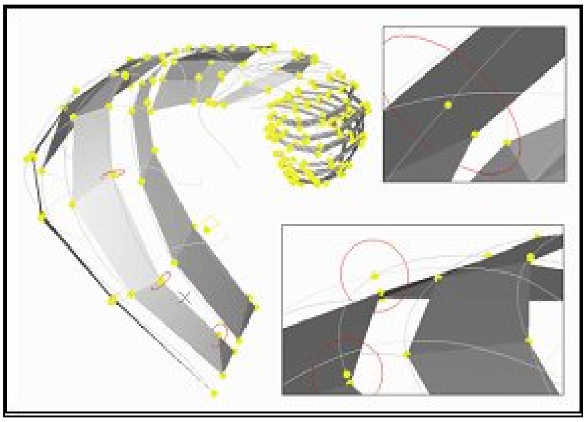

Figure 18. Striations in External Fabric. Dritsas &Gunji, 2005

Structural expression / clarity

The expression of the structure is intrinsically tied to the external form of the project. The structure is supported form points on the existing building and in turn supports the external cladding panels. Linking the structural elements to the rest of the parametric model means that any changes to the form of the building can be mapped in relation to their effects on the supporting structure. The use of accurate 3D models has allowed engineers Arup to analyse the evolving design in terms of structural requirements. Linking the design of the form and structure through the digital environment increases the clarity of structural expression (Figure 19). The structure can also be made to be highly efficient, and both these factors contribute to an increase in the overall quality of the building.

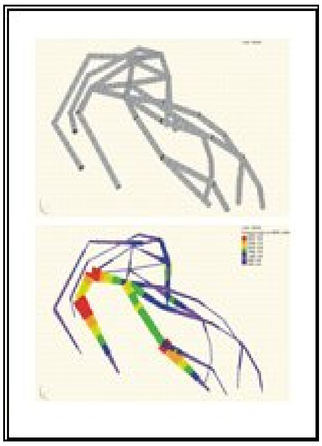

Figure 19. Structural Analysis. Dritsas &Gunji, 2005

Buildability & Health and Safety

The complex geometries of the external form are being rationalised through the digital environment so that the project can actually be built. The surfaces are facetted to avoid complex curves that would to be difficult to fabricate. Because of the complexities of the shapes involved and the differences between glazed and solid panels, the form could only be rationalised digitally. In order to reduce the number and weight of components required, the external panels are designed as rigid, composite panels including waterproofing, insulation and structure. CAD files giving the 3D dimensions of each panel derived from the digital model are used to drive CNC machines, making use of the concept of mass-customisation. This facilitates the cutting of the complex shapes in a single process, reducing the time taken in construction, and minimising the transport of materials and the erection time required on site. The effect of this is that high-

Figure 20. Pre-fabricated Panels. Dritsas &Gunji, 2005

precision prefabricated panels can be used to make up the very complex form quickly and simply, increasing the buildability of the project, with little increase in cost (Figure 20).
It is also arguable that the highly pre-fabricated panels will reduce health and safety risks as they only need to be bolted together, removing many of the on-site processes. As this amount of pre-fabrication stems directly from the use of the digital model to drive the process, it can be said that the use of avant-garde digital techniques results in an increase in quality through a reduction in health and safety risks on site.

Innovation

The Bankside Paramorph clearly demonstrates the effect that digital techniques can have on architectural innovation. This project involves the realisation of one of the most complex forms of any building to date, something that would be unachievable without the continuing advances in digital technology.

5 CONCLUSIONS

We have seen that the use of avant-garde digital techniques had a large impact on the delivery of quality over many key aspects of the design and construction of the Chesa Futura and Bankside Paramorph. This is true across all three major elements of quality: functionality, build quality and impact. Digital techniques were perhaps most important in terms of impact, because they enabled the construction of such an unconventional form. Linked to this impact, parametric tools enabled the functionality of the scheme to be maximised, without which the scheme might not have been viable at all. We have seen that the build quality of the scheme as a whole was increased by the use of pre-fabrication of much of the building, a technique which was again enabled by the design of the building through the digital environment. In short this unique building that *“exceeded the client’s expectations”* was dependent on the use of digital technologies. The digital environment permitted the designers both to create new forms and to deliver a building of great quality
Parametric/Relational modelling techniques

An integrated design process involving digital environments is becoming indispensable in the design of today’s buildings. As we have seen, through the development of parametric and relational geometry, CAD tools are able to parametrically vary design concepts keeping in step with design intent and, therefore, resulting in a greater overall quality. The next step in digital design lies in considering the computer as collaborative partner in the design process capable of generating ideas and solutions in response to robust and rigorous models of design conditions and performance. For instance, new ways of designing structure and architectural form in parallel are emerging based on generative process in which the generative software acts as an enabling partner amongst architects and engineers to produce unimaginable forms that are efficient and buildable.

Scholars in the field of Architectural computing are arguing that digital environments are triggering a two fold paradigm shift in architectural design. On the one hand, digital generative processes are opening up new territories for conceptual, formal and tectonic exploration. That is, instead of modelling the form, designers articulate an internal generative logic, which then produces, in an automatic fashion, a range of possibilities from which the designer could choose an appropriate formal proposition for further development. On the other hand, “file to factory“ production methods are originiating a new concept: mass-customisation. Construction has, until now, based on the industrial mass-production of building components. The elements are produced as generic material which will be customised later in another phase of the life of the product. The mass-produce elements are categorized into discrete classes: doors, beams, windows, etc. The components are produced in a limited range of sizes, then stored and catalogued, until eventually ending up in an assembly in a factory or on-site as part of a building. Mass-customisation follows a different path. There is no catalogue; the products are produced from raw material for a specific purpose, to become a unique part in a unique setting in a specific building. The savings made in automating the process means that costs for one-off components hardly different to the old standarised components. Mass-customisation of the house would bring the best to a wide market and quality design would not cater to the elite.

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Texto de los pies de cada figura

Figure 1. Traditional Design Methodology (Fischer & Herr, 1998)

Figure 2. Generative design as a design methodology (Fischer & Herr, 1998)

Figure 3. Gaudi's analogue generative system (Mitchell, 1977)

Figure 4. Window Pattern Generator (left) and patterns in a real facade

Figure 5. Parametric Object (left) and glazing system in real building

Figure 6. *International Terminal,* Waterloo Station, 1993, London, UK. Architect: Nicholas Grimshaw & Partners. (Kolarevic, 2003)

Figure 7. External View of Chesa Futura (Glover & Koppitz, 2005, pp11)

Figure 8. Comparison between rounded and orthogonal forms (Fantoni, 2002, pp4)

Figure 9. View from balcony (Glover & Koppitz, 2005, pp13)

Figure 10. Parametric Model (Fantoni, 2002, pp9)

Figure 11. Exploded axonometric of structure (Glover & Koppitz, 2005, pp12)

Figure 12. Pre-fabricated sections (Fantoni, 2002, pp5)

Figure 13. Detail of External Finishes (Fantoni, 2002, pp11)

Figure 14. Chesa Futura and surrounding buildings. (From *"Schindelhaus auf Stelzen",* 2003) Photo: Patrick Blarer

Figure 15. Project Location: Bankside, London. Dritsas &Gunji, 2005

Figure 16. Parametrically Variable Model. Dritsas &Gunji, 2005

Figure 17. External Form. Dritsas & Gunji, 2005

Figure 18. Striations in External Fabric. Dritsas &Gunji, 2005

Figure 19. Structural Analysis. Dritsas &Gunji, 2005

Figure 20. Pre-fabricated Panels. Dritsas &Gunji, 2005