Computational Design Consultancy

*Interface Between Construction Disciplines*

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**Abstract.** The pervasiveness of the digital media has set the ground for tighter collaboration between the discipline involved in the architecture practice and potential for reconfiguring the well-established communication patterns in the industry to occur. Considering the context thereof, Computation Design Consultancy aims to connect different considerations and priorities raised by different parties involved in the architecture production system by means of digital computation. Here, we discuss the inefficiency of the existing system in engaging with the contemporary context influenced by the digital media as well as our approaches and findings thus far through the consultancy work.

**Keywords:** Consultancy; Communication; Interactive Software.

**Introduction**

In recent years, digital media have become prevalent in the architecture industry, where most of the parties involved are utilizing various software tools in order to perform some of their tasks. Though software tools generally try to facilitate the production within each party, they do share a common underlying representation of information in digital form. The fact that a consistent representation of the problems, intentions and solutions enclosed within each domain exists is significant since it sets the ground for a rearrangement of the architecture production system to occur.

Computational Design Consultancy is an experimental role we take in an engineering office, with architecture background, aiming to reach out to the potential innovation offered by the new media. The main difficulties in providing such consultancy do not come from technical issues but rather from a rigidity of the established system in the practice. Therefore, the focus of the paper is not on the details of specific solutions developed for projects but our observation of the current system as well as our effort in trying to transgress the existing boundaries by computational approaches.

**Existing System**

The current architecture production system inherits its structure from the time of industrial revolution where the division of labor in manufacturing was developed in order to adapt to the technological development at that time. The system is often conceptualized as a tree structure where complex entities composing the production are divided into units [architect, engineer, fabricator, etc] and linear construction phases are used to measure the progress of the projects [Design Development, Tender documentation, etc.]
The tree is a hierarchical structure that operates efficiently when the execution sequence is clear. In this type of structure, any kind of unexpected scenario is a disturbance such as a communication short circuit in the system (Alexander, 1964). The weakness of such a structure is revealed, for example, when faced with ‘complex forms’ designed by architects using so called ‘free form’ design software tools. This in not to dismiss the ability of the media to handle geometries that were difficult to work with in the past. The current production system implicitly assumes the design to be rectilinear and has been refined to avoid failures under this rule. Therefore, when this precondition is reversed at the top of the tree, the system has very little knowledge in how to execute the processes. Because of this, an unthinkable amount of trial and error occurs. The consequence of the technological development is not bound to the formal issues as we can observe the increasing demand on practices to operate at high speeds by processing unprecedented amounts of information. In such the system should be guided to a new equilibrium.

**Contingency planning**

Karatani (2001) in his ‘Architecture as Metaphor’ discusses how the term architecture has been conceived in philosophy as a realization of design qua idea. He however, in order to deconstruct this misconception, refers to architecture as a practice being an event par excellence exposed to contingencies.

“Nothing is less relevant to the reality of architecture than the idea that it is the realization of design qua idea. Far more critical factors are involved, such as the collaboration with other staff members and the dialogue with and persuasion of the client. The design as initially conceived, is invariably destined to be transformed during the course of its execution.” (Karatani, 2001)

There is a problem however when architects themselves have forgotten about the contingent character of architectural production, and instead embraced the misconception that Karatani attempts to dispel. We see architecture practice as a contingency planning aiming to realize the design not as an idea that becomes tainted by the realization process but as a problematic field that becomes enriched by contingencies. Each contingency then creates new rules in the system and fine tunes the previous ones.

**Computational Design Consultancy**

Architecture is contingent and the rapidity of current technological developments coupled with commercial demand for unconventional buildings are forcing the existing system to become a tremendously complex and laborious process of trial and error. However, as is usually the case with new technologies, existing systems of construction presents a lot of rigidity in regard to the current influx of new techniques. We can observe two ways in which the current practice is trying to improve the wastefulness of this trial and error. One approach tries to speed up the process of the trial-error loop using digital computers, and the other approach tries to stiffen the tree structure by introducing more layers of management. In fact in the field of project management all the contingencies are considered to reduce more labour and risks and various approaches are developed to monitor or reduce such scenarios.

Similarly, our consultancy work tries to reduce the wastefulness in the system that seems devastating for a creative community, however, from a different perspective. We believe computational solutions flexible enough to integrate different concerns raised by various parties involved in the production could better deal with the contingent nature of the practice. As partial subjects of the system, the difficulty lies in finding new ways to connect existing disciplines reconfiguring the well established communication patterns.

The following projects illustrates our approach and findings discussing both the failures and successes of the interaction we attempted to establish while providing such consultancy.
Interface between design software and structural analysis software

DRL10 pavilion, Architect: Alan Dempsey and Alvin Huang
Stage: Structural Analysis
Disciplines, Architects, structural engineer, Fabricator, material research

The DRL 10 is a small pavilion designed to mark the 10th Anniversary of the Digital Research Laboratory program at the Architectural Association. The geometry was designed in Rhinoceros as doubly a curved surface and was intersected with a series of planes to generate the structural ribs. The ribs are placed in a mesh like configuration with gaps between them in both direction so as to fabricate individual elements from standard sheets of Glass Fiber Reinforced Concrete (GFRC). GFRC is a very thin concrete sheet with high structural performance in plane. However, the challenge of the project was to use the material in a weaker direction to hold the entire pavilion.

The computational design consultancy in this project was an internal service in assisting engineers to build FEM analysis models in Sofistik from the architects’ models in Rhinoceros.

The current software tools utilized in architecture community generally try to facilitate the production within each party (architecture, engineering, fabrication.) The translation of the models between them is one of the fundamental obstacles in developing integrated solution to a project that yields problematic conditions in various levels. One of the problems which are the time it takes in the conversion process. This is particularly evident when faced with projects with complex geometry as the translation of the models tends to take a lot of time away from both the architects and engineers.

DRL 10 pavilion illustrates the effect of minimizing the model translation time because of its challenging geometry, material use and the short time frame given. Here we should clarify that a structural analysis model is not a direct translation of geometric information from a cad system. A lot of information has to be added like cross-section, beam orientation, springs and other finite elements that model specific behaviors at joints. In this project selecting one by one members and assigning cross sections and orientation would not have been realistic. In addition, because of the short time available the engineering model itself had to be parametric so that engineers could easily explore a range of solutions like for example deciding an overall skewing factor for the structure in the early stages.

By developing a project specific conversion software tool we were able to quickly respond to the request from the engineers in testing the structure that was counter intuitive in its structural behavior. In fact at the end, we produce more than 100 FEM models for the project in a few weeks which would have been impossible otherwise.

Facilitating the communication between the engineering and architecture software tool is a base for many of our consultancy work. However our intervention in this case was limited to speeding up the traditional work flow between architects-engineers based on a continuous trial and error loop and intuitive decisions. The large number of models required in the end reflects the slow convergence of such procedures.
**Geometric analysis, cost estimation and fabrication information for a large number of unique panels.**

Haidar Aliyev Cultural Centre, Architect: Zaha Hadid Architects  
Stage: Construction / fabrication  
Disciplines: Architect, Fabricator, contractor, Structural engineers, cs, façade engineer

Haidar Aliyev Cultural Centre is a project proposed to be built in the capital of Azerbaijan designed by Zaha Hadid Architects. The overall dimension of the building is approximately 170m x 156m. The roof, which is the focus of our consultancy work, is designed as a series of ribbon-like surfaces, that has the total area of more than 40000 square meters. In this project, Computational Design Consultancy stood mainly between the architects and the fabricators in assessing the external roof cladding composed of a large number of unique panels early in the project. The particular stage in the project required the analysis of the overall surface as well as properties of individual panels in order to estimate the relation between design decisions and cost. Handling a large number of discrete information is trivial in computation yet communicating the correlation between complex parameters to the whole project team is

![Figure 2](image1.png)  
**Panel analysis and cost estimation**

![Figure 3](image2.png)  
**Fabrication information and panel rationalization**
one of the most challenging aspects in our consultancy work. This is partly because of the various parties involved in the production tend to have different modes of communication. For example, visual communication is better suited to architects whereas numerical descriptions and spread sheets work better with engineers. Developing the software tool that reveals the visual effects of numerical input and vise versa helped the involved parties to better understand the correlation between the design alteration and panel cost and facilitated the decision making process. For example, our real-time software tool was used in deciding acceptable thresholds of curvature and inter-panel angles [numerical] at which panels could be considered flat without producing a visible faceted effect [visual.] Moreover, even though the fabricator at this stage was not yet decided, we tried to assist and highlight the possible direction in which the fabrication information could be produced from the same software tool.

Relatively early into this study, the penalization concerns were decoupled from the engineering concerns of the underlying steel structure. This was made possible by the introduction of construction details that would compensate for the discrepancies between the two as well as the appointment of a façade engineer that became responsible for the layer between the outer skin and the inner steel structure. Working within the current system of production from within an engineering firm, this development led to systemic and budget problems for us.

**Design of openings on museum roof using inverse illumination**

Architect: [at the moment we cannot be disclosed]
Stage: Competition
Disciplines: Architect, environmental engineer

The consultancy work for the project, which we cannot disclose at this moment, was undertaken during the competition stage. Our focus of the project was to develop an optimal roof opening solution that satisfies the internal lighting conditions [architectural concerns] that are environmentally efficient throughout the year [environmental concerns], which fit inside the required structural depth [structural concerns]. Optimization here is not considered as a scientific method but as a process of performing selective information filtering that steer these complex and contradicting design problems towards a well-negotiated form. Here we will discuss how the development of the computational solution intervenes in the communication loop between parties involved, in order to improve both quantity and quality of information exchange.

In many cases there is required information specific for developing solution that are not possible to mediate through descriptions and text. In this project, the desired lighting conditions from the architects were difficult to communicate as they were constantly changing the design necessary in the competition stage. In order to establish a flexible
input system for the architects to communicate the information, we developed a minimal input interface. From our previous experiences, we found it difficult to engage people with no computation background when we distribute the complete software that exposes all the functionalities. Complicated interfaces and the underlying algorithms seem to confuse people and decrease the interest in taking such path. Hence the interface used by other parties are minimal, user friendly and implicitly ask for very specific information required in generating the design solution. Therefore, two sets of interfaces were developed in parallel; one for architects to input, and the other for the computational design team to develop the solution and the interface necessary in communicating the relationships between input parameters and output.

The project was the most successful thus far in terms of communicating the possibilities and the flexibility of our solution to the team since the simple and clear request for information have propagated to the involved parties without destructing them with technicalities.

**Embracing Contingencies**

Architect: Future Systems  
Stage: C-E  
Disciplines: Architect, structural engineer, (environmental engineer, Fabricator)

The project is a roof that is designed by the architects as a doubly curved surface [a trimmed NURBS surface] dipping in the middle to form an atrium. For this roof design, the main communication has been taking place among the architects, engineers and us, the computational design team.

The initial concern for the architects was to distribute the roof openings approximately following the lighting requirement derived from programmatic constraints. The first step of each project is to render such architectural concerns suitable for computational representation. In addition, it is important to define the problem as generic as possible such that other considerations and contingencies can be dealt with in the later stages. In this case, the main problem was not the opening shape itself but the density and directionality of the opening distribution pattern.

Therefore, we opted for an algorithm that can generate a mapping / reparameterization of any surface topology that complies to given scaling and directional conditions expressed as a pair of orthogonal vector fields. A good candidate for the input vector field from an engineering perspective would be the two principal stress eigenvectors taken from a finite element analysis of the given surface (Felippa, 2006.) This field is chosen under the assumption that for a large enough surfaces with a fine material continuity, preservation of the material continuity along the principal stresses will result in some structural efficiency while at the same time it will reveal and imprint something of the structural behavior of its form. In order to be able to locally control the scaling of the pattern we employed an algorithm described by Ray N., Chiu Li W., Levy B., Sheffer A., and Alliez P. (2006) called Periodic Global Parameterization.

The project faced three major contingencies, up to now, that led to formal changes yet, expressing the architectural requirement as density [lighting conditions] and the engineering one as directionality [material continuity along principal stress directions] were both preserved throughout the project.
Initially, the roof had a Star of David pattern in which the triangles guarantee a planar solution for the strut problem. [Star of David pattern, Framing solution]

**First event: Insurance issue related to the waterproofing**
[Circular pattern, GRP solution]
For this event where the structural solution and opening geometry had to change, we just adjusted the mapped pattern, while the algorithm we used made sure that material continuity was preserved along principal stress directions.

**Second event: Neighbors of the house appealing for a lower roof height**
[Change in global geometry, ellipsoidal pattern] This change in the global geometry had virtually no effect on us as the algorithm is capable of handling any input surface geometry. However, the architects, at this point, decided that the lower patterns will be elliptical openings. This meant that special consideration should be taken for some holes to align with the principal curvature directions so as the flat glass panels for the openings do not deviate too much from the outer surfaces.

**Third event: limitation on available transportation means.**
[Introduction of joints] The incorporation of mechanical joints in the roof implied additional consideration because areas around the joints would appear as solid zones on the surface. First we tried to influence the position and shape of joint so that they fall in areas of minimum bending moments and in addition to disturb the pattern less. However this was not entirely possible due to the internal wall position, so in the end there was a clash between the pattern and the joints. To accommodate this we had to alter the control field of the patterning so that it blends smoothly around the joints. This was achieved by taking advantage of another field the gradient of distance map(Wang, Wang, Tang, Yuen.)

We tried to cope with contingencies by adding information gained at each stage to our program and developing functions to extract the desired solutions (Michalatos and Kaijima, 2007.) Because we opted for an algorithm where the solution is controlled through vector fields the design problem itself was transformed into the complementary problem of constructing a vector field that best negotiates project constraints.

![Figure 6](image) Distance map and its gradient and tangent fields.
Conclusions

The biggest obstacles in the projects did not come from the contingencies of the design itself and its realization but from rigidity in the current system of production as well as the ambiguous role of computational techniques in design as it is not yet clear for other parties what is it for or how they can take advantage of it. Eventually computational design should not become a support discipline for architects but rather dissolve and affect all the involved parties in the same ways that IT technologies have disappeared by becoming ubiquitous in the design and building process. We hope that in the future this signifier of Computation Design Consultancy will express a desire to develop a deeper understanding of digital representations as well as put pressure to the system to move to a new direction rather than remain static but rigid or dissolve in incoherence.

References

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