Digital Tools and High Performance Architecture

Revising the design process' organizational structure

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Abstract. *This paper briefly recounts how computational design has surfaced in the architectural discourse during the recent decades, developing into what is now called parametric design. In this context, the authors argue against Parametricism, an avante garde movement which is limited to the issues of style and aesthetic fitness, whilst an approach that uses parametric modelling, simulation and visualization in an iterative way to generate design solutions for complexities of contemporary design problems is favoured. Following a discussion supported by representative examples from current practice, a possible organizational structure more appropriate to take advantage of digital tools to increase design performance is suggested.*
Keywords. *Performative design; parametric design; design methodologies; design team structure.*

INTRODUCTION: COMPUTER ARCHITECTURE AND COMPUTATION IN ARCHITECTURE

An interest in the possibilities of using computation and parametric tools in the design process has become increasingly apparent within the architectural discipline. After several decades of using computers in architectural practice, a consensus has formed that not only values digital tools for increased efficiency in tradition activities, but also acknowledges that contemporary software can enable an iterative systems approach to design that surpasses the original objectives of Computer Aided Architectural Design (CAAD) and the commercially available software of the time. Though obvious, the fact that computing is altering not only design processes but design methodologies is quite complex and a rather slow development. To describe this, Nicholas Negroponte has discussed phases of 'absorption' and 'adaptation' as ordinary processes that occur when new technology is presented. The 'absorption' of computing into the architectural practice has spanned the past three decades, during which persistent improvements in hardware, computing power and software have created a promising circumstance for the 'adaptation' of computing into the practice of architecture.

Intending to solidify and increase coherence for this new movement, Patrik Schumacher states, „Contemporary avant-garde architecture is addressing the demand for an increased level of articulated complexity by means of retooling its methods on the basis of parametric design systems. The contemporary architectural style that has achieved pervasive hegemony within the contemporary architectural avant-garde can be best understood as a research programme based upon the parametric paradigma." (Schumacher, 2008, p. 1) After establishing the criteria and describing the characteristics of the evolving style which he calls Parametricism in a 2008 manifesto, Schumacher's ambitious agenda has involved an attempt to establish the validity of Parametric Design as an important movement within the history of architecture. Indeed, there has been significant attention towards computational design in architecture and much of it has been relegated to the field of aesthetics and high levels of interest in the generation and articulation of complex geometric configurations. Yet, despite these efforts to substantiate a new style in architecture, there is a natural denigration of this proposal when the wastefulness of the lavish exuberant aesthetic proposals is demonstrated.

Contemporary architectural design problems involve the resolution of variables that require computation beyond human mental capabilities. This is an iterative process that mandates the consideration of an extraordinary amount of components through modeling, simulation of performance, and analysis. Parametric design caters to this process in that it requires the articulation of relationships between components and creates a framework that allows the designer the flexibility to evolve design proposals.

SOME SHORTFALLS OF THE USE OF COMPUTATION IN CURRENT ARCHITECTURAL PRACTICE

Not pretending to undertake exhaustive analyses, but only as examples illustrating what we see as the worst case scenario in terms of favouring superfluous shape and image over the basic environmental performance requirements of a building, we have chosen two projects by Zaha Hadid Architects [2] in the United Arab Emirates, the first is the Performing Arts Centre in Abu Dhabi, and the second is the Signature Towers in Dubai. The projects were 3d modelled according to image data encountered, and analysed in terms of internal temperatures and HVAC energy requirements using two different software packages. At the same time, hypothetical buildings of equal dimensions using vernacular construction technologies were also modelled and analysed to serve as reference points for comparison.

It is not necessary to know much about building physics to understand that in a climate like that of the U.A.E. (with high solar radiation, important day cycle temperature differences and changes in relative humidity), thermal mass, solar protection and natural ventilation could be of great help as passive strategies to bring internal temperatures of a building near to comfort conditions.

The above mentioned was verified by getting the weather data of Abu Dhabi from the data base of the software Meteonorm [3], and exported for visualization using WeatherTool, an add-on to the software Ecotect [4] (Figures 1 and 2). According to generic predictions using that software, thermal mass and natural ventilation could substantially elevate comfort percentages for a building placed in such climate (Figure 3), and could on their own be sufficient to attain internal comfort levels during the months of March, April, May and November.

On the other hand, the use of glass in important proportions, especially when there is no solar protection (even if using low emissivity glass types), implies important heat gains that would remain in the building. A building of such nature would need important amounts of energy to be employed in the HVAC systems in order to maintain comfort conditions inside. As mere examples, we shall discuss the two projects mentioned before, compare them to vernacular solutions and briefly evaluate their implications. It must be stressed that since the information available was very limited, we could not pretend to claim any precision in the resulting data of the analyses run, however, they give a good idea of the extent to which the environmental performance of this sort of projects compares to that of local vernacular constructions, and to general standards for energy consumption in buildings.

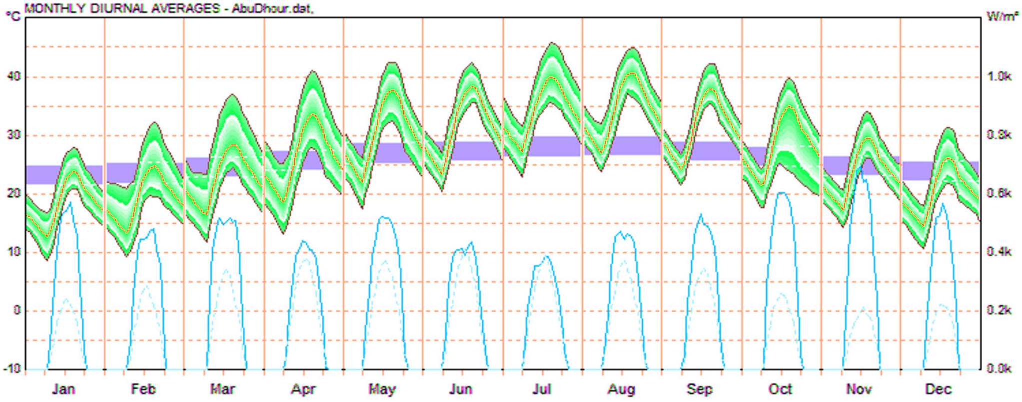


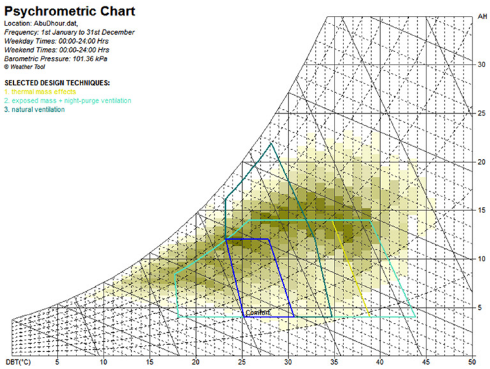
Figure 1
Hourly temperatures (Max, Min. Average) for typical days of each month in Abu Dahbi.

Performing Arts Centre, Abu Dhabi, U.A.E (ZHA)

This building with a total area of 62.770m2 to be located in the Saadiyat Cultural District of Abu Dabhi should integrate various theatres and concert halls. After 3D modelling the external envelope of the building (Figure 4), the concert hall situated at the north end was selected for analysis using EnergyPlus [5] via DIVA for Rhino [6]. The analysis area was of 4190m2, with a surface of 17500m2 including a 55% glazed area on the 4 exposed faces. The walls were defined as plastered concrete of 2500mm and the glass chosen was clear Low E Double glazing consisting of two 6mm panes separated by a 13mm argon filled cavity.

Results from simulations for that space using the above mentioned parameters, and without using HVAC systems give temperatures above 50C at the peak of summer (24th of July) and above 30C in winter (14th of January), thus requiring the use of cooling systems even at the peak of winter. At the same time, a space with the same dimensions but with a window ratio of 25%, solar shading and masonry walls of 50cms (implying high thermal mass and low heat gains) would only reach a maximum internal temperature of 44C in summer and 21C in winter, as can be seen in Figure 5.

While both spaces would require the use of HVAC systems, analyses giving a setting point for cooling at 22C and for heating at 18 did show an



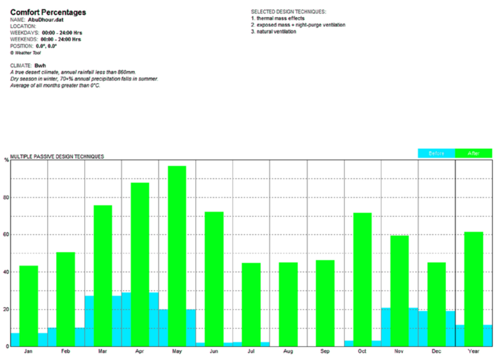


Figure 2
Psychrometric chart for Abu Dabhi

Figure 3
Comfort percentage improvement predictions by using thermal mass and natural ventilation in Abu Dabhi.

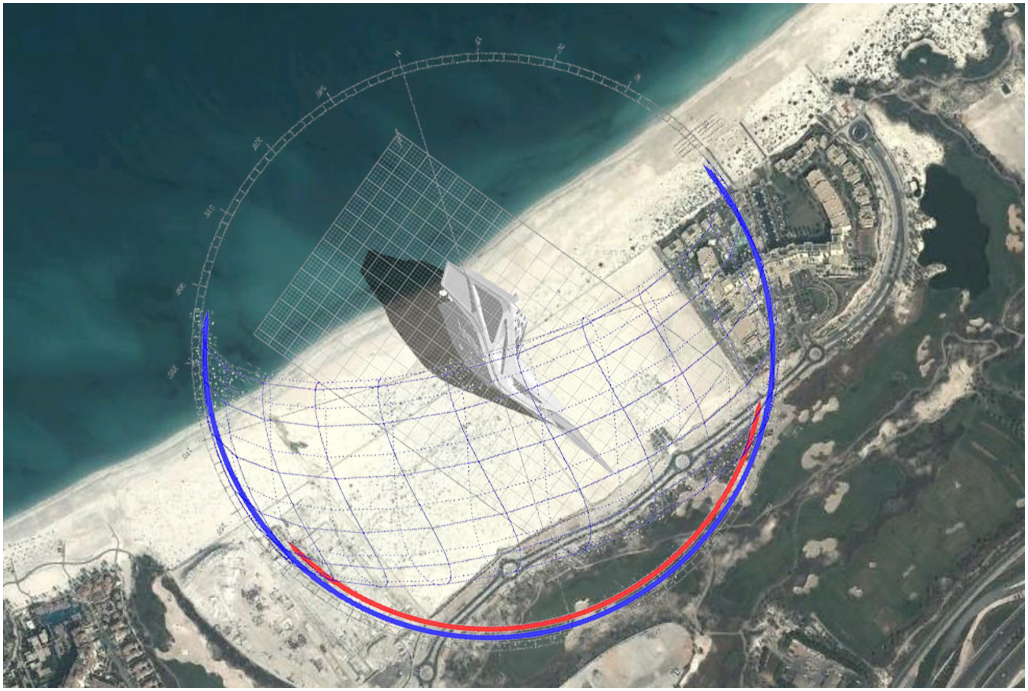


Figure 4
Top view of building on location showing solar trajectory.

annual consumption of 961160Kwh for the ZHA project, giving a 229Kwh/m2a standard compared to 49250Kwh for the high thermal mass option, giving it a 117Kwh/m2a standard (Figure 6). If compared to general standards for office buildings from 50 Kwh/m2a to 20 Kwh/m2a (Hegger et al., 2008) this is still very high consumption, it should be noted that the height of the space is significant, and consequently large volume of air per m2 are given.

Signature Towers, Dubai, U.A.E (ZHA)

These towers are to be situated in the centre of Dubai's financial district, with a total area of 650.000m2 and a top height of 377m (75 storeys) (Figure 7). An area of 3100m2 equivalent to a floor plan for two interlocked towers with a surface of 3000m2 was chosen for the analysis. The enveloped assumed a 2500mm concrete construction with an 85% glazed area, slabs defined as concrete of 5000mm and the glass chosen was clear Low E Double glazing consisting of two 6mm panes separated by a 13mm argon filled cavity.

Results from simulations for the space using the above mentioned parameters, and without using HVAC systems gave temperatures above 60C at the peak of summer (24th of July) and above 40C in winter (14th of January), again requiring the use of cooling systems even at the peak of winter. At the same time, a space with the same dimensions but with a window ratio of 40%, solar shading and masonry walls of 50cms (implying high thermal mass and low heat gains) would only reach a maximum internal temperature of 49C in summer and 34C in winter, as can be seen in Figure 8.

In this case, analyses giving a setting point for cooling at 22C and for heating at 18 did show an annual consumption of 400500Kwh for the ZHA project, giving a 129Kwh/m2a standard compared to

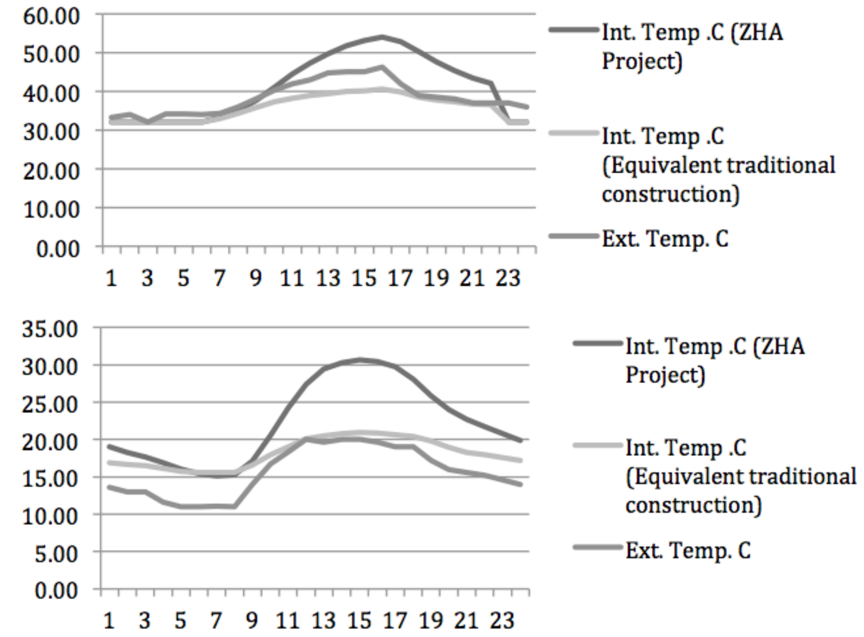


Figure 5
Exterior and interior temperatures in the main auditorium for July 24th (top) and January 14th (bottom) (without using thermal machines).

205000Kwh for the high thermal mass option, giving it a 66Kwh/m2a energy consumption standard (Figure 9).

COMPUTATIONAL TOOLS AND THE DESIGN TEAM STRUCTURE

Supported by the examples shown above, we would like to start a discussion where we argue that there is something fundamentally wrong in the way digital tools are commonly used by architectural design practices these days, particularly when it comes to achieving decent performance levels of any kind.

While it is true that digital tools have the potential to manage and process complex data concerning environmental or other problems whilst taking into account parametric relationships, it would take an important degree of specialization in order to take the appropriate decisions at each step in the design process. In this view, the still predominant scheme of the star architect who has deliberate control upon all major decisions in a specific design goes directly against the inner logic of the auto-poietic nature of

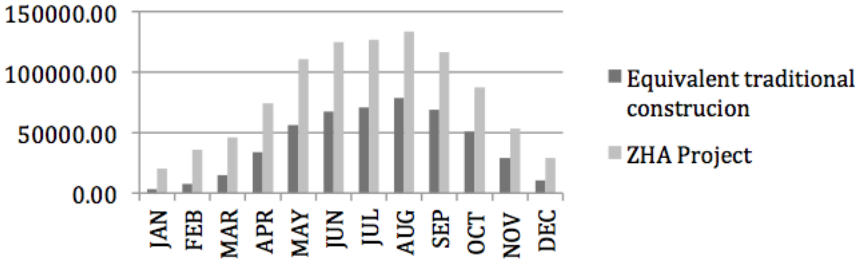


Figure 6
Energy consumption for HVAC systems in Kwh per month.

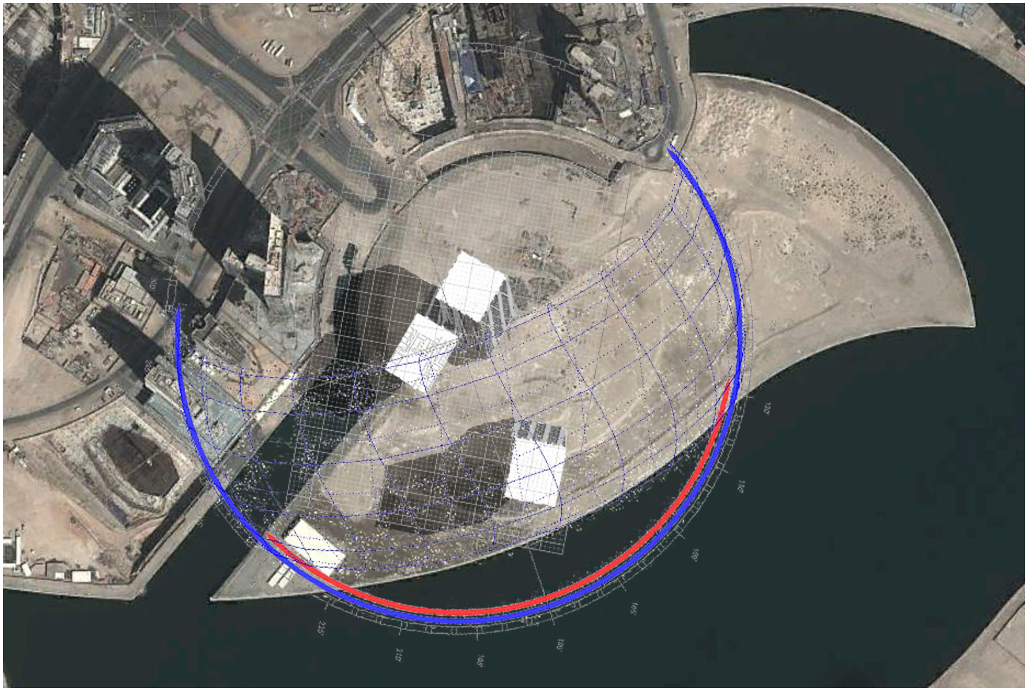
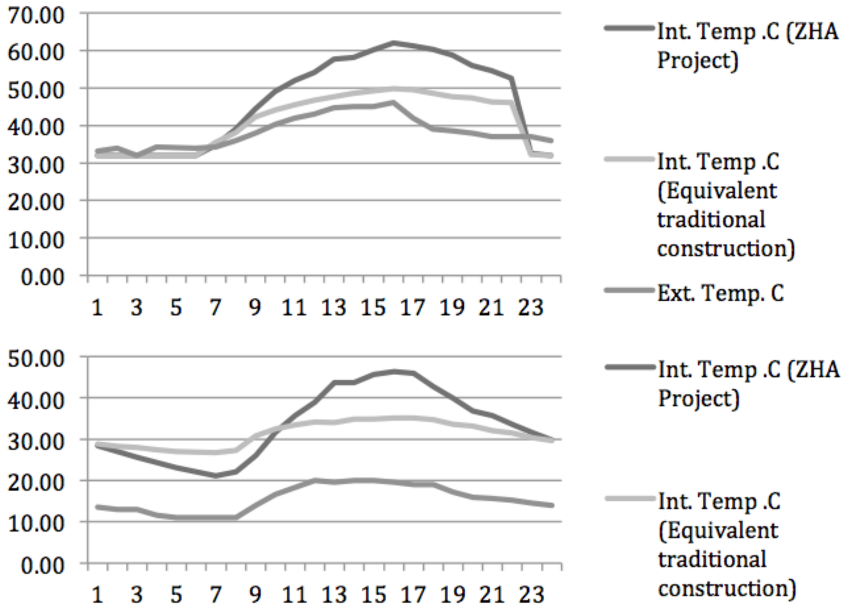


Figure 7
Top view of building on location showing solar trajectory.

such tools, as no human would have the mental capacity to make informed decisions about so many diverse and yet complex situations to be dealt with in the conception of an architectural design (clearly some less than others). Yet, many well-known architectural practices, specifically noted for the use of digital tools inside their practices, as we have seen above, make such formally capricious and seemingly ignorant decisions when it comes to performance (not only in terms of eco-environmental aspects, but also in terms of structure, materials and construction), which could only sharply contrast the analytical potential of rightly applied digital processes.

From a process based organizational perspective, it may be argued that the problem with the use of digital tools to generate ecologically and otherwise high performance designs lies in the position where such tools are placed within the organizational chart of architectural, engineering and construction practices along the design process. It would seem that in order to manage the scientific requirement for specialization and yet have a design based approach on the decisions encountered at each architectural level, the team structure should be much flatter, composed by empowered sub-teams of architects and engineers that would interact among themselves to evolve and generate appropriate designs based on iterative analyses provided by digital tools. These emergent (in both senses) practices, of which we can already find a few examples, by working together represent a new organizational model for architectural practice (Knippers, 2013) that may be far more efficient and able to make the most of the power that digital tools have in order to create highly ecologically and otherwise efficient buildings.

Table 8
Exterior and interior temperatures in the main auditorium for July 24th (top) and January 14th (bottom) (without using thermal machines).

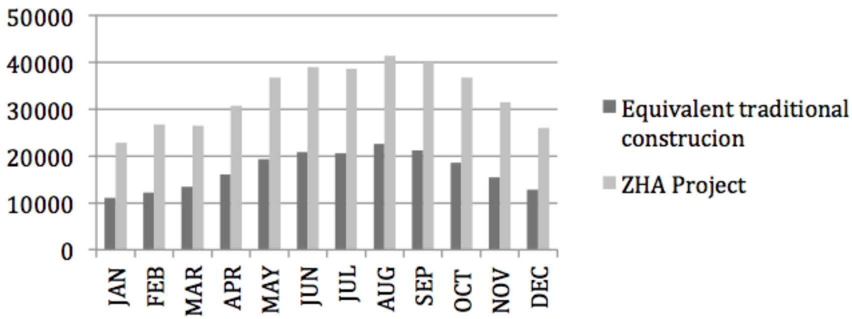


A SHORT CAVEAT CONCERNING "OPTIMIZATION"

As it has been said, the relatively recent but still growing development of digital technologies, translated in an ever increasing capacity for data management, is having important consequences to the way we conceive, design, engineer and make buildings, tending towards an inclusive seamless process allowed by the homogenous nature of digital data. In this respect, the new possibilities opened for engineering and design as a single entity are probably best represented by digital optimization processes, where a given physical configuration (design) represented as 3d data is analysed against specific performance aspects (simulation) in an iterative process where particular design parameters are allowed to mutate in such a way that it becomes possible to evaluate a great amount of possibilities and choose from them the better performer.

However, as seductive as this idea of optimiza-

Figure 9
Energy consumption for HVAC systems in Kwh per month: Comparison between the studied project and an equivalent construction using traditional construction techniques



tion may be, it is also a very dangerous one, particularly when overestimated but superficially applied, usually by agents with little understanding of the actual optimization problem. In fact, with the popularization of tools for the task that are accessible to non-specialists, in the area of architecture, for instance, it is becoming already common in schools to find students using tools like Galapagos [7] without having the remotest idea of the consequences of the process, but nonetheless producing data, and for that reason believing that because it is data it should be right. The acronym GIGO for the popular saying from the early days of computing seems now more relevant than ever.

As for possible ways out of this dilemma, it can be said, that since the key to the problem lies in the necessary specificity of any kind of optimization, it is then of primary importance to completely understand the scope of the phrase or concept directly following the proposition for after the word optimization, that is, such design is optimized for (constructive, structural, environmental, functional) performance when in use, and following from that, understanding not only the particularities of the problem (what does environmental performance, etc. means in that case) but also, and probably most importantly, realizing for which other aspects the same design is not optimized; only an exhaustive and unbiased evaluation of that situation would give the designers a balance of the real value and limitations of the data produced. A very interesting point about the necessary degree of redundancy (Weinstock, 2006) found in Nature just in the same extent as optimization could be very useful in this respect.

CONCLUSION

"… Resulting from the process of programming technical and qualitative parameters, the form will reveal itself in negative against the decision plot of options and possibilities which will form the unity of the project. The project will not be revealed until the last moment and will no longer preside as the subjective precedent of the architect's work… This signifies that the language of engineering is genetically integrated with the calculations, that the engineer is a cohesive and a simultaneous partner in the development of the project… (Mygayrou, 2012)

We briefly recounted some of the implications that the use of digital tools is having on the design process in architecture, and have argued for a performance conscious approach as opposed to a stylistic approach, this last one exemplified by two current projects from a recognized practice where the use of the latest computational tools and access to highly qualified engineers does not seem to help them to get a minimally environmentally performing design. We then suggested that since the problem does not seem to lie neither in the tools themselves nor in the technically specialised personnel in charge of using them, it is the actual organization of the team that should be revised. Making a caveat regarding optimization processes as they start to be used, more emergent processes seem to be required to take good advantage of the possibilities opened by digital tools. While it would be naïve to hope for a completely bottom-up process based on data, it is clear that the organization of the design process needs to be revised.

According to that, this paper does not provide any clear answers, but can be understood as a warning against common failures of current practice regarding the application of digital tools when it comes to high performance architecture, and an invitation to study the possible dynamics of emergent practices where architecture and engineering are interlocked through the whole design process, using digital tools as a common language, not only to produce technically efficient buildings, but also meaningful, for that should be the natural outcome of integral performance in architecture.

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