

Emergent, Adaptive and Responsive Urban Landscape Design Strategies

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Abstract

The practice of design is experiencing new and revolutionary approaches created by the information technology and digital tools that have entered into a truly effective and operational phase. Three hundred and sixty degrees of the world of design is affected – from architecture to urban design, from product design to landscape design. Parametric, associative and generative design tools deeply influence the practice of design; on the one hand allowing professionals and researchers to develop integrated and dynamic environments with multi-functional and sustainable buildings; and on the other, constituting the operational and concrete base for the deployment of a new aesthetic consciousness based on the digital technologies available in the practice of design.

This work discusses the latest work methods provided by the new digital tools and technologies and investigates the outcomes in order to exploit their potentialities in terms of integration, performance and innovation; or to underline the critical points and propose ways to improve their use in order to mind the gap between potentialities and applications. Three case studies, all produced by the author, will be presented. The employed research method is the *critic chart*, an objective/subjective evaluation method that includes a comparison of the given design attributes that are defined as valuable and listed in charts, and the final result of the projects. The results will be presented in the form of an illustration with a discussion of the projects’ characteristics and features. The works to be analysed fit the various aspects, requirements and ideas, objectively and subjectively, even if with various gradients. The new methodologies and potentialities created by digital tools permit the development of designs that properly fit the environment, and are sustainable, performative and an expression of the cultural complexities and multiplicities of the contemporary world.

Keywords

Bottom-up, process, generative, integration, interaction, optimization

Bottom-up design

“Everything is what it is because it got the way” (D’Arcy Wentworth Thompson, 1917). Nowadays we are witnessing the great influence that digital tools are having on contemporary design production and research – from both the operational and aesthetic point of view. This influence is so strong that we speak of this new trend in design as a style called *Parametricism* (Schumacher, 2008). Parametric, associative and generative approaches are fast-developing contemporary technologies and methodologies that, by using different digital tools, allow *bottom-up* design strategies to be applied to all kinds of design.

The new digital technologies of design are characterized by the creation of project models made exclusively of correlations between project elements features and specifications, both internal and external, before the form is generated as a model. The interaction between the design characteristics and features, from the first steps to the most complex organization, make the project a *bottom-up* system capable of optimizing and improving the use of internal resources and increasing adaptation and interaction with different environmental conditions. Therefore, the resulting integrated design represents a sustainable system from many points of view. *Bottom-up* design strategies work similarly to the genotype/phenotype principle of biology and take place through transformation and adaptation processes. “[...] in this way, architecture is considered a form of artificial life, subject, as in the natural world, to the principles of morphogenesis, genetic codes, selection and auto-similarity” (Frazer, 1995).

The *bottom-up* strategies that characterize the use of contemporary digital design tools present some very interesting analogical precedents. The experiments for form-finding by the engineer Frei Otto at the Institute for Lightweight Structures in Stuttgart, which he founded in 1964, called it a “system of the optimized path” (Otto & Rasch, 1996). It was able to search for the form of optimal configurations for some specific materials through the interactions of two factors: the intrinsic characteristics of the matter and the external conditions of the environment. In the case of soap film suspended on a frame, the form configuration was dependent on the elastic property of the liquid material and the spatial arrangement of the frame. Every time it was modified, the surface changed accordingly to configure in the optimal way to that specific situation, constituting a minimal surface. From these form-finding studies, the project for the tensile structure covering the public areas around the Munich Olympic Stadium in 1972 was produced.

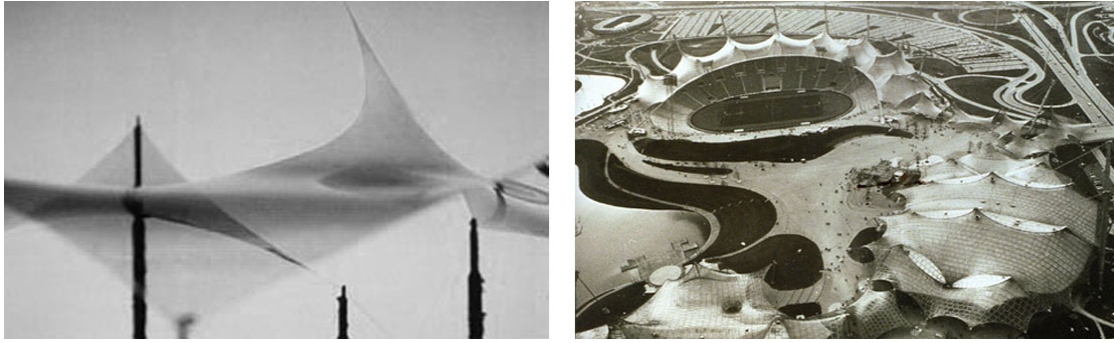


Figure 1. Minimal surface studies using soap films. The Munich Olympic Stadium by Frei Otto.

A second empirical machine by Frei Otto that applied a *bottom-up* methodology was a circular frame with wool strands. Once the regular lattice pattern had been immersed a few times in a liquid that contained glue, the strands started a process of densification sticking to each other in an apparently casual fashion. However, on the contrary, the clusters that formed by the end of the process were the optimal solution generated by the interaction of the internal characteristics, the free length mass and position of the strands, and the external conditions like the differentiated density of the glue in the liquid. The final configuration "[...] is not weak but rigid and compact, with a soft stiffness [...] It is not random, it is ordered, with a vague order, the randomness is replaced by variation" (Spuybroek, 2005).

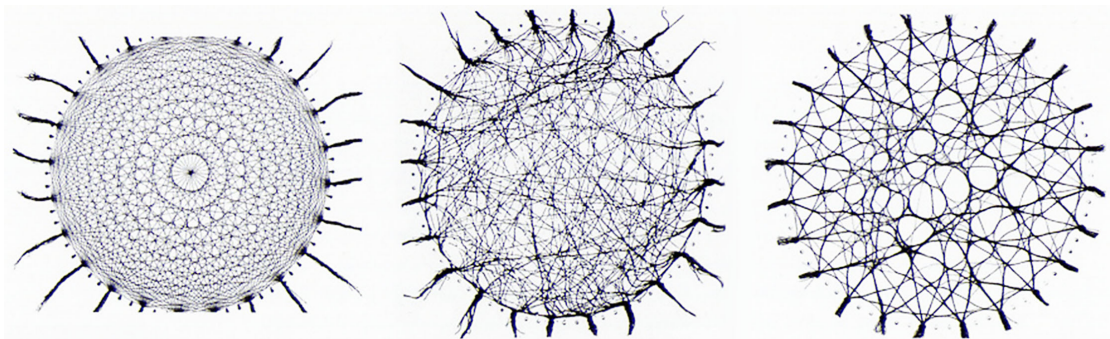


Figure 2. Schemes of the empirical strands of the wool machine by Frei Otto.

Perhaps the most brilliant experimental research and use of *bottom-up* methodologies applied to architectural design in pre-digital time was by the architect Antoni Gaudí with his inverted models of the Sagrada Família structure. The concept was designed to analyse the strengths along the catenary arches and all the structural frame of the church structure by hanging a number of ropes, corresponding to the structural elements, up-side-down and thereafter attaching a series of weights at the nodal points of the structure to the ropes. In this way, the configuration of the frame was dependent on the mutual relations between the different elements and the application points. By changing even one rope length, weight, size or application point, the whole structure reacted, thereby leading to the most efficient and strongest possible shape. The results of these interactive and dynamic studies were realized in the structure of Gaudí's great church in Barcelona.



Figure 3. A model of the Sagrada Familia structure inverted and suspended by Antoni Gaudi (left and middle). Interior of the actual church (right).

As seen in these examples, the *bottom-up* methodology, nowadays applicable to design by parametric tools, creates interrelations between the project elements that are never univocal but always multi-directional. In this way the modifications operating at one point of the system or parametric model will be transmitted in a relational system, at different scales and with different results to all the other elements, even if they are not directly connected to the first. In this way, the final result or form of the design is generated autonomously by the model with the designer making a few critical decisions at crucial steps of the process. If on one hand, the architect loses total control of the final outcome, on the other, he or she gains a better design process that leads to an unprecedentedly integrated, responsive and specific environment. “The task is to develop an architectural and urban repertoire that is geared up to create complex, polycentric urban and architectural fields which are densely layered and continuously differentiated” (Schumacher, 2008).

Creating projects, and consequently built environments, that are fitted to the initial requirements and specifically integrating into an environment with which they will interact, increases the performance in terms of the optimization of spaces and functions and the wellbeing of the people, while minimizing the impact in terms of energy consumption through the use of passive solar techniques, devices and proper material, in order to create open and accessible urban landscapes. These are some of the goals that parametric design aims to achieve. Two factors make this possible: the use of objective data as the starting inputs of design, which, later on during the process, eventually is evaluated and modified by the subjectivity of the designer and the integration of all the different data, like the internal project characteristics and specifications with the external environmental conditions.

After the presentation of the digital design created by using parametric tools based on *bottom-up* methodologies, the methods for the research will be discussed.

Critic charts

The method used for the analysis of the works is a *critic chart*. The comparison between the relevant and objective attributes and the initial purposes, as well as the corresponding characteristics of the projects, are used to analyse and evaluate the qualities or critical points, as well as the appropriate or incongruous aspects of the presented designs. For this purpose, an

evaluation diagram has been designed for each project with three specific interpretation sections, each one referring to a critic idea of architecture or to a specific reference system.

The first is that of architecture as expression of the contemporaneity. Based on Manuel Gausa's diagram *Dynamic Time* - *formal order: <un>disciplined trajectories* (Gausa, 1999) a number of characteristics and elements have been identified that represent new paradigms in architecture and urban landscape with the advent of new urban phenomena, a new consciousness about ecology and information technology. Consequently, these are the keywords: interactive, dynamic and combinatory.

The second section takes into account aspects that are nowadays called good practices. For this purpose, the triad of *firmitas, utilitas, venustas* as presented in Vitruvius's treatise *De Architectura*, has been interpreted in a contemporary context. *Firmitas*, the characteristic of being a solid building, is nowadays feasibility in terms of costs, norms and constraints. *Utilitas*, the usefulness of an environment has been considered as is, i.e. to be usable and accessible in all its parts. *Venustas*, beauty in terms of the proper application of the classical codes and architectural proportions, is today the user-friendly experience. No matter how a project has been thought of or conceptualized, by adopting certain methods or creating a design using a specific set of tools, the final result should satisfy general criteria that make an architecture or an urban environment feasible, usable and friendly.

The third is a self-referencing control system. As it has been pointed out above, working with *bottom-up* methodologies that use parametric digital tools allows unprecedentedly integrated, respondent and multi-layered environments to be created. This is because of the organization of the work that allows the designer to create the relations and the connections between the project's internal and external elements. Consequently, the mutual interactions and modifications from the bottom up happen as a kind of evolutionary process over which the architect has only partial control. Therefore, it is interesting to use a system for evaluating the characteristics of the final outcome in relation to the initial designer concepts and project requirements in this research. Here, the keywords in the *critic chart* will be different depending on the project being analysed.

Case study 1. Interferred Urbanscape

Smichov is an unused industrial area near the city centre of Prague on the banks of the Vltava River. The assignment for the designers competing in the European 6 competition was to revitalize and reconstruct the area with residential, commercial, office, cultural, green, sport and leisure space that should ideally reconnect this abandoned area with the life and history of the nearby city centre.

The aim of this project entry, called Interferred Urbanscape, was to achieve an integrated system rather than a closed development, in which the functions could be mixed to form a complex environment of interconnected activities and areas. The final outcome should not simply be a new block of the city but an urban landscape area where all the functions would merge and integrate with each other, as well as with the natural elements and the surroundings. The design concept was to interpret the area not as a group of spaces, but as a series of fields. The interaction between the flows and forces of the fields was to generate the project layout. Parametric and

generative digital tools (Gravity Space Warps and Particle Systems) using animation software were used to simulate the interactions of the project's environmental elements.

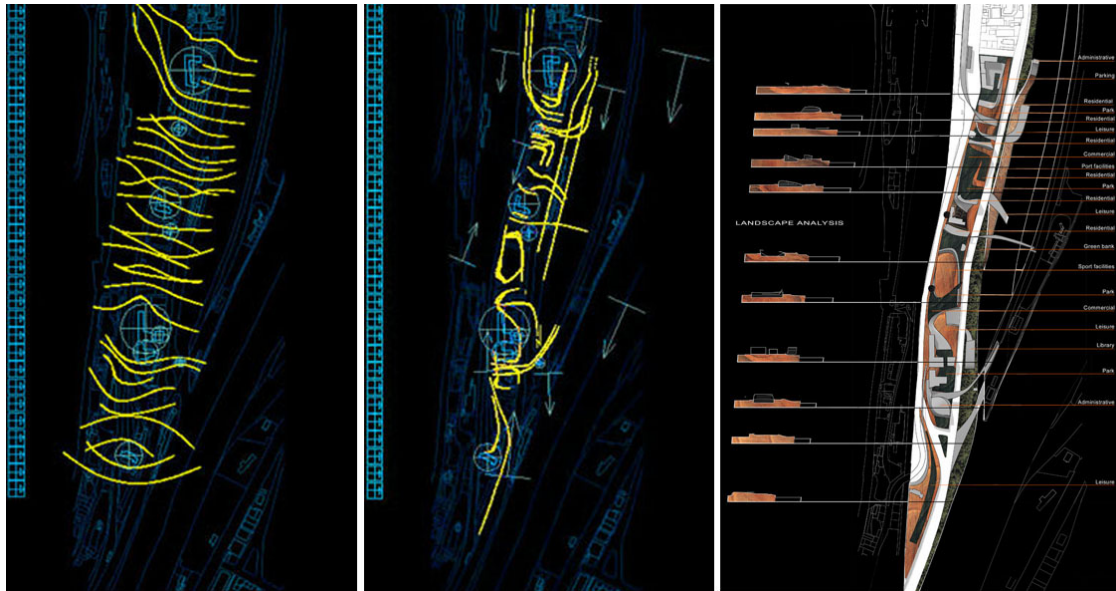


Figure 4. The process for bending the generative flow vectors. The final urban landscape in the Prague project.

The flow vectors passing through and moving in the direction of the city centre conceptually reconnect the area with it and interact, at first, with punctual forces like gravitational fields placed in correspondence to the abandoned industrial buildings that are architecturally and functionally valuable to reuse. The flow lines swerve creating a modified pattern. Consequently, these deformed flow lines interact with the linear forces like deflectors representing the main morphological and activity signs in the area like the river flow, the large railway assets and railroads, and the main traffic road, all shaping the site in the same direction. With further bending and folding, the flows generate the final evolutionary pattern. This was used as a trace to design the layout of the required buildings and environments based on the designer's ideas and concepts.

Comparing the *critic chart* created on the basis of the two general interpretation sections and the one relative to this project, the final outcome has a high level of interaction with the environment, as well as being very dynamic and combining the functions and spaces in a complex and open way. The project has a certain level of feasibility, but is not simple since all the parts are different and consist mostly of complex shapes. It is usable and accessible because of the sequence of open spaces that connect the built-up parts, and is friendly due to the small scale of the buildings and their balanced integration into the natural elements. The use of site-specific elements and green areas in the generation of the layout makes the project a well-integrated landscape of built and open spaces that creates an optimal mix of functions.

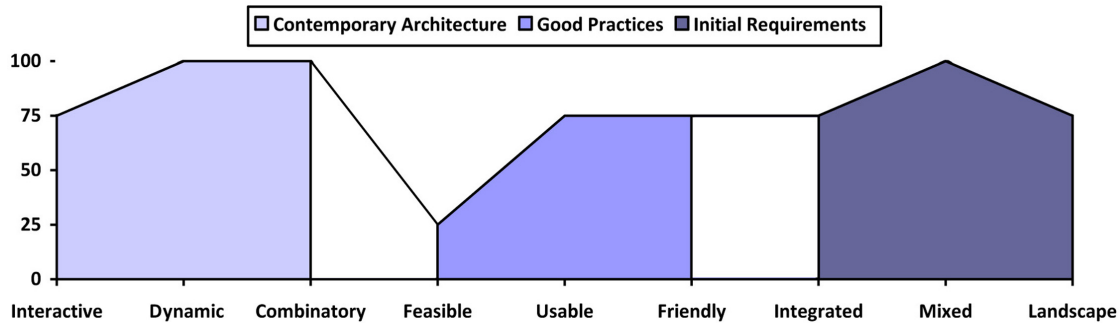


Figure 5. Critic chart for the Interferred Urbanscape project in Prague.

Case study 2. Coral City

Typhoons and tropical storms are the main causes of natural disasters in the Philippines, and the devastation increases every year due to climate change. Design against the Elements was a competition promoted in 2009 in the Philippines to design sustainable and disaster-resistant development in tropical urban settings, in Quezon City, Metro Manila. At the same time, the scope of the competition included the gathering of ideas to use as models in the design of other disaster-resistant settlements. For the latter, the basic requirements were a high level of flexibility and adaptability that would generate different residential options for the same area, starting with a few basic types, and the ability to replicate the main concepts in other settlements. A special focus was to be given to sustainability as a key issue in fighting environmental disasters, thereby helping to decrease the causes of climate change.

The project named Coral City proposed an interpretation of architecture as a metaphor of nature. The idea that the role model for the project concept had to come from the natural environment is based on the fact that the organisms that populate it, like corals, always represent the best solution to a certain problem, resulting from evolution, adaptation and self-organization. Voronoi is a geometrical tool available in parametric and associative design programs that subdivides an area into optimal cells. For the proposal, the block with an internal court as a residential type was used because it emphasizes social life and decreases energy consumption due to good ventilation. After having input the possible sizes of the apartments and limits of the building depths, different kinds of subdivisions layouts were parametrically generated for the lot. Consequently, the configuration that allowed for the best layout of the remaining areas for the church, school and community centre was chosen by the designers.

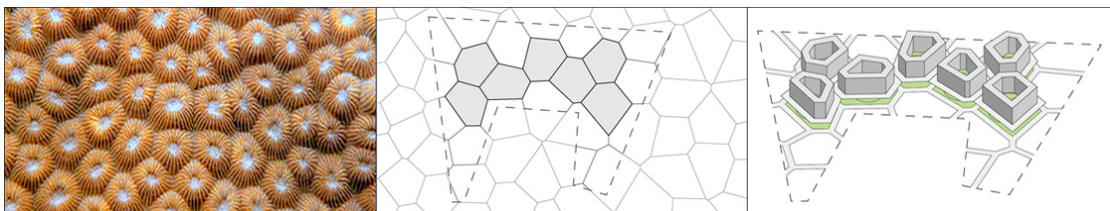


Figure 6. Self-organizing structure of a group of coral. Adaptive plot layout through Voronoi subdivision.

The different residential unit types were developed based on the modular elements and features for the purposes of cost-effectiveness. The parametric and associative design was first used to develop different residential types sharing characteristics with the basic type, and then for the distribution of the residential units into the different blocks. Associations were created between the units sizes and features and the block sizes, orientation and circulation layout. This permitted an optimal distribution of the units in relation to the amount of floor space. Then the features of each unit, such as the internal layout, window size and shading devices, were parametrically adjusted depending on the orientation and reciprocal position. The supporting structure was implemented as an integrated part of the parametric design process, and step by step all the modular units were put in place.



Figure 7. View of the model of the Manila project realized through a parametric design process.

The resulting design creates a strong interaction with the plot, the site and the environment, and it can be dynamic depending on the plot layout. At the same time, it is highly combinatorial for the modularity of the living units. Combinations between the functions were not considered as an option. Due to the use of parametric and associative design tools for the definition of the architectural parts, the project is highly feasible with controlled construction costs. In the same way, the functions are well distributed and usable. As required by the competition brief, the design tool based on the Voronoi plot subdivision can be adapted to other areas with different geometries; the unit distribution is extremely flexible and proper shading devices guarantee a high reduction of energy consumption.

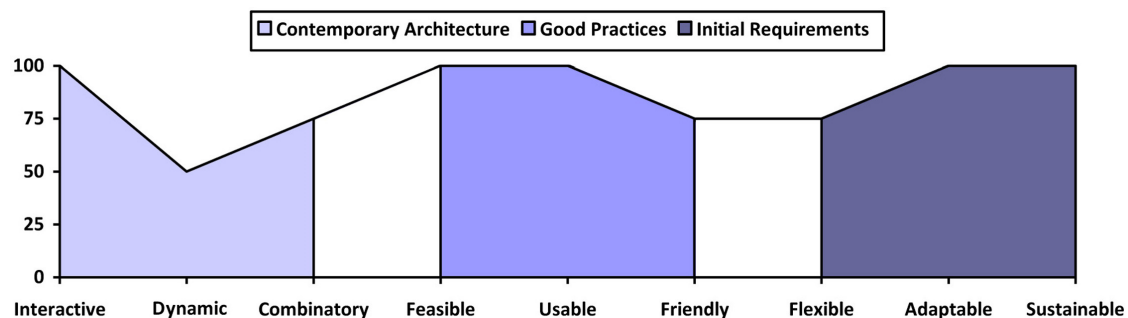


Figure 8. Critic chart for the Manila Coral City project.

Case study 3. The Poblenou Experiment

In the middle of a culturally and socially active area of Barcelona, we find a street with the typical layout of a Spanish *rambla*. It was once a centre for industrial activities, and has a pedestrian walkway in the middle with cars on the sides, and is therefore a place of social rather than vehicular communications. It cuts through the Cerdà grid in an area where the layout of the blocks did not develop as a unifying model due to the fragmentation of the activities, mainly small industries with differentiated residential accommodations emphasizing the idea of diversity and mutability.



Figure 9. Views of the Rambla del Poblenou in Barcelona.

The Rambla del Poblenou is a place for the rearrangement of the layout of public spaces based on conceptual design. The aim of the project was to study possible processes using digital parametric tools that could generate diagrams embedding the specific and differentiated characteristics of the area that could be adapted from place to place. At the same time, the outcome was to represent a performative model and operative tool that could be used by the architect to find a series of configurations feasible to be developed further in a proper project design.



Figure 10. Location of the record points along the urban space for the experimental design.

The physical environmental data comprised the input parameters for the design process. A custom device with electromagnetic, temperature, movement, sound and light sensors was used during the fieldwork to record the sets of data in relation to the specific places along the study area. The places were chosen because they marked critical parts on the street to remodel, like roads intersections, small gardens or benches areas, cafés with tables and small monuments. The readings were repeated on two different days to obtain an average of conditions.

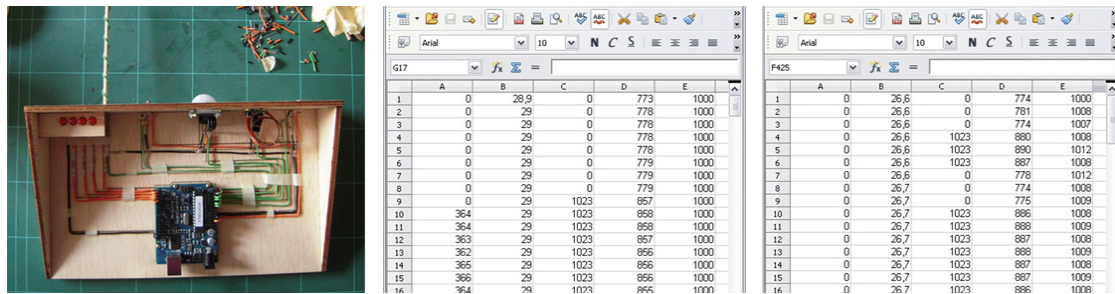


Figure 11. The environmental sensors device and data to be used as parameters in the design process.

The streaming of the objective data was used as a first step to build the parametric model of the conceptual project. The different conditions along the path, the temperature together with light, movement with electromagnetism, and sound, transformed into parameters and associated with geometries generated a three-dimensional diagram for visualizing the needs of the specific areas. The variation in temperature, due to direct sunlight, provided information about where to create shading devices, their sizes and orientation. The different movement behaviour of the people indicated how to differentiate spaces like small squares by providing pedestrian paths and gathering areas, excluding where the electromagnetism were too high. The data on the sound and amount of traffic noise indicated how to differentiate the design by creating sound barriers. Once the objective data and the geometric output have been finalized, the role of the designer is to interpret the outcome and use the interpretations for the next subjective design stages. The result of the parametric design is a tool that the designer can use to generate design solutions.

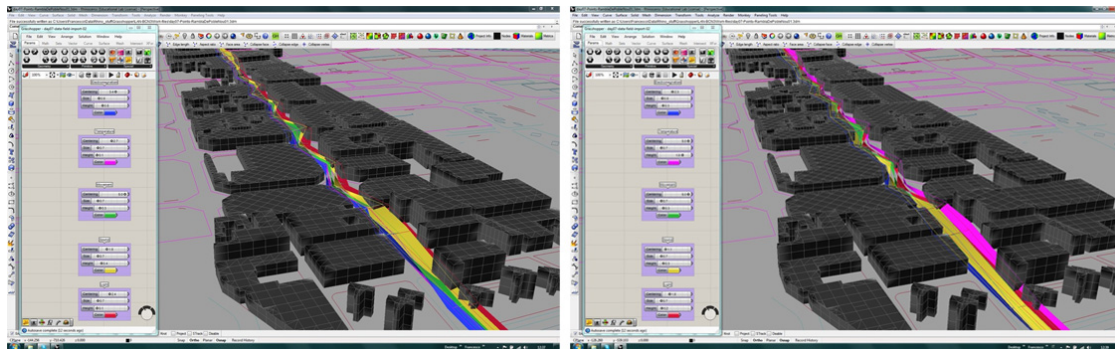


Figure 12. Two possible configurations of the conceptual design based on the objective environmental data and the subjective manipulation of the design algorithm by the designer (left image side cursors).

The complex environmental model built in this way is very interactive, dynamic and combinatorial based on the interactions that are created between the site conditions, the possibility to make dynamic modifications of the interactions in order to study their different effects and the multiple combinations achievable by the design solutions. Since the starting point of the parametric design process was the site data, the final outcome totally accomplishes the initial aims of being extremely performative, specific and differential. This is due to the data simulation that allows the designer to obtain the best performances, the variation of the specific conditions measured from place to place, and the differentiation in the design outcome that is achievable thereby, while

keeping the entire project as a whole. For this case study, the Good Practices interpretation section of the *critic chart* has not been considered due to the conceptual level of the design.

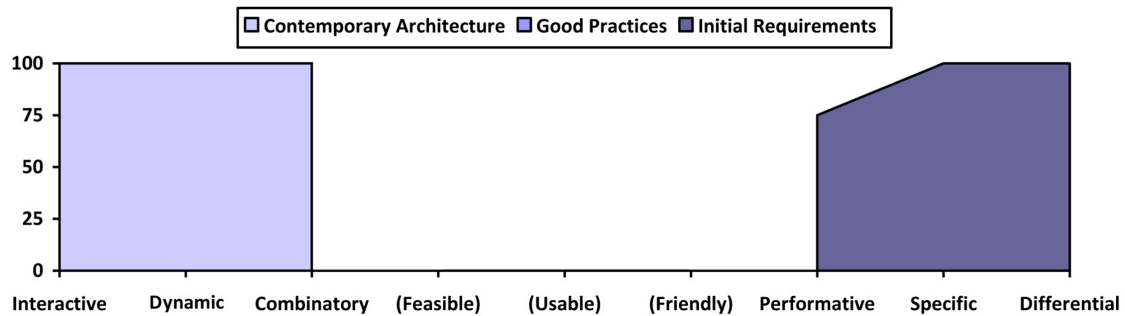


Figure 13. Critic chart for the Barcelona Poblenou experiment.

Results

The case studies presented and analysed through the *critic chart* have shown how the parametric, associative and generative tools permit different results for the various attributes on the base of the characteristics, as well as the scale and level of details of the projects to be achieved. In general, the outcomes of these *bottom-up* methodologies present an outstanding average of values compared to the more consolidated way of design sometimes referred as the *top-down* method. This shows how these tools make the creation of proper designs possible by comparing initial requirements, integrated and sustainable environment, the feasible and usable outcome, and being an expression of our contemporary environment at the same time.

In the first case study, the urban design of an unused industrial area in Prague, the use of the parametric and generative tools at the concept project stage produced very good results for the first and third chart sections – Contemporary Architecture and Initial Requirements. The Good Practices section got a medium average mark because it was decided to use the *bottom-up* generative methodology with no practical restrictions, so it generated completely unexpected results, and it was used only in the conceptualization phase of the design without any further implementation in the subsequent stages.

More specific restrictions were used in the project for the disaster-resistant development in the Philippines due to the competition requirements. In this case, the inputs related to the real needs from the concept phase were used to study the layout of the plot, brought to more homogeneous level of distribution. In any case, the concept phase that was connected to the Contemporary Architecture interpretation section had a lower score because the use of associative tools resulted in greater emphasis being placed on the development of a feasible idea that could fulfil as many of the initial requirements as possible.

On the opposite side is the conceptual design for the refurbishment of public spaces in Barcelona. Due to its strong experimental character, the Initial Requirements coupled with those of Contemporary Architecture, and the Good Practices were not taken into account. The parametric design was used only at the very beginning of the design process by presenting a very interesting application of the *bottom-up* methodology. The purely objective geometrical representation of

environmental data made the highest score in the first and third interpretation sections of the *critic chart* as a whole. Anyway, since real and site-specific data were used in the experimental design, these also constituted an objective basis for developing the project further with the aim of obtaining the best result in terms of feasibility as well as usability.

These results make it clear that the use of parametric tools can enhance the results of the outcomes offering strong potentialities to architects and designers to produce proper and integrated as well as feasible and sustainable designs. At the same time, the results presented here are usually related only to a single design stage, or, in other words, do not affect the whole process. Even if the conceptual phase is well developed and the design concepts are interesting, the architectural project can lack feasibility, or the parametric design tools can only be used for the optimization of the construction and costs, which can lead to buildings of poor architectural quality. As we have seen, there can be exceptions, in which more design phases can simultaneously take advantage of the potentialities of parametric tools, but still only for some phases and never for the whole process.

Conclusions

The previous illustrations and discussion have a double outcome. On one hand, the great potentialities, and on the other, the uneven results of the application of parametric, associative and generative digital design tools. Naturally, the designers' way of thinking is continuous from the general to the specific, from the large to the small scale, from the global to local aspects. Parametric design, on the other hand, focuses on the specific problems or steps of a project, contributing dramatically to find the optimal solutions, but at the same time tending to fragment the design process.

This demonstrates the necessity for architects working with digital *bottom-up* methodologies to develop design processes that integrate the use of the various parametric design tools during different project phases, at multiple scales and for different requirements. This can be achieved by adopting the illustrated procedures, not only as tools to achieve a specific result, but as strategies inside a more complex integrated process.

The structure of a tree also resembles the organization of some parametric software, where the leaves are connected to the small branches, these to the large branches, and then to the main trunk; parametric design should also work to connect the single and detailed project features with the appropriate design aspects, integrating them into the relative project phase and merging them for the final outcome.

The results in terms of a single architectural building or urban landscape environment would be a more homogenous integration of the different characteristics and greater average quality of the different aspects. This would represent a real and significant advancement in the professional practice of contemporary design.

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The Poblenou Experiment project was developed by the author in collaboration with Arch. Oriol Carrasco during the Live Parameters LAN (Live Architecture Network) workshop at the Institute for Advanced Architecture of Catalonia (Barcelona), in 2010.

All the images are the work of the author or are part of the author's archives.

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Biography

PhD Arch. Francesco De Luca graduated with honours in Architecture and defended his PhD thesis in Architectural Design and Theory at the University of Rome "La Sapienza". He has received several awards in international architectural competitions including 1st Prize for *A Concept Plan of Pärnu's Riverside Centre* and the *Design against the Elements* Special Energy Prize. He has published various articles and a book called *Behind the Scene – Avant-garde Techniques in Contemporary Design*. After teaching at the L. Quaroni Faculty of Architecture in Rome as a contract professor, he is now a researcher at the Tallinn University of Technology. He is a co-founder of the ITA Project architectural design firm.