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## **Combinatorial Architecture**

### **Methods for the creation of ambiance in public space**

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**Abstract.** *Atmosphere refers to an impalpable condition with the capacity to influence our feelings. Making an urban atmosphere means creating an impalpable condition through the execution of a series of specific operations: spatial, geometrical, sound acoustic, and climatic. This operation signifies the transformation of the qualitative into the quantitative, the non-measurable into the measurable, and the intangible into the tangible. This paper discusses the Combinatorial Architecture methodology, which was developed by the author as a proposal for a methodological model for architectural design. The methodology was developed in the research Lab Non-Linear Solutions Unit at the GSAPP Columbia University, consisting in the manipulation of attributes and building blocks to determine quantitative and qualitative parameters of a public space. Recent case studies explore two different ways in which Combinatorial Architecture can transform public spaces: The first case study, Instant Installation, First Street Green Park, commissioned by the City of New York, shows how the combinatorial methodology can be used to develop multiple configurations and transform the ambiance of an existing urban setting. The second case study, the wind turbine park the Whirlers, presented in 2014 at the RENFORUS Conference at UNESCO, shows how the Combinatorial Architecture methodology can be used to develop unprecedented forms of public spaces connecting renewable energies and urban life.*

**Keywords:** *combinatorial, attributes, parametric, performance, associative, urban, urban ambiance*

*'A great building must begin with the unmeasurable, must go through measurable means when it is being designed and in the end must be unmeasurable.'* Louis Kahn

## **Combinatorial Architecture**

Atmosphere refers to an impalpable condition with the capacity to influence our feelings. Atmospheres can sometimes be recorded or surveyed, but to make an urban atmosphere means the process of creating an impalpable condition through the execution of a series of specific operations: spatial, geometrical, sound, acoustic, and climatic. This operation signifies the transformation of the qualitative into the quantitative, the non-measurable into the measurable, and the intangible into the

tangible (Tiazzoldi, 2012). *Combinatorial Architecture* includes a method in which quantitative and qualitative parameters (i.e. social, physical, sensorial, cultural, and economic) are integrated to in the architectural design process through the development of a three-phased architectural design model. The *Combinatorial Architecture* methodology offers an educational and professional decision aid tool that assists decision-makers in fixing the priorities related to an urban morphology, architectural design, and functional, technological, or engineering problem. The implementation of the *Combinatorial Architecture* methodology supports architectural reasoning through the development and refinement of research tools and computational methodologies; a conceptual and instrumental platform and service to the scientific, architectural, and engineering communities; and a contribution to the science of learning by providing an innovative methodology. From a methodological point of view, the *Combinatorial Architecture* process takes advantage of research done in other scientific fields, specifically in the field of cognitive sciences (Holland, 1999).<sup>1</sup> The method is inspired by research on genetic algorithms and complex adaptive systems and by work on biological variation (Bateson, 1979). *Combinatorial Architecture* explores a theoretical methodology to achieve a new form of urban organism and news forms of experience in public space. The method has three phases inspired by the mechanisms of the genetic algorithms consisting of a sequence of procedures from (1) creative reductionism to a (2) new population and a defined (3) solution.

The first phase, defined as 'creative reductionism', consists in analysing the environmental conditions, translating them into elementary units and attributes that can be adjusted during the architectural design process. During this phase, which was initially developed in the field of cognitive science (Holland, 1999), it is possible to fragment a non-measurable entity into a set of numeric data and to identify the logic connecting them, transforming what is non-measurable into something measurable. It is a creative act unfolding new fields of the measurable. In architecture, the creative reductionism phase corresponds to decomposing a given reality into a set of elementary units (i.e walls, windows, openings, slabs) and their attributes (i.e. thickness, length, rotation, scale, reflectivity, transparency, porosity, and sound absorbance) (Tiazzoldi, 2009). The second phase, the 'new population of solutions', is the process by which the *Combinatorial Architecture* methodology creates a 'new population' of possible solutions by associating the different attributes and building blocks and by defining a variety of rules and a proliferation of similar units. The second phase also consists in expressing the hierarchical system organizing the different variations. The third and last phase in the *Combinatorial Architecture* methodology is the process of 'selection'. This phase identifies those configurations among the solutions tested, which can provide an appropriate correlation between the input and the possible solution of an architectural question. The third phase of the method requires the definition of a series of architectural and design performance parameters, selecting which unit in the new population of solutions better responds to the program and requirements (Tiazzoldi, 2009).

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1. 'Any human can, with the greatest of ease, parse an unfamiliar scene into familiar objects – trees, buildings, automobiles, other humans, specific animals, and so on.' (Holland, <http://cscs.umich.edu/~crshalizi/reviews/holland-on-emergence>)

Ultimately, this phase focuses on the selection of the solution that better responds to the qualitative or quantitative parameters defined by the architects and the design team.

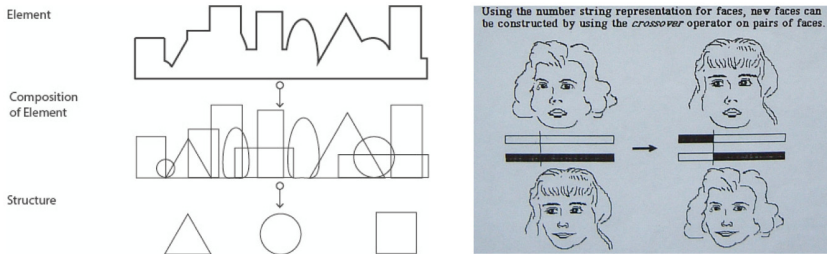


Figure 1-2. Combinatorial Architecture methodology diagram representing the method of fragmenting an intangible reality environment into a set of data attributes and material properties that can be recognised and transformed throughout the architectural design process. Diagram representing the method of attributes and building blocks manipulation to create new solutions by combining the different attributes and building blocks. (J. H. Holland)

The method described above will be further examined in two recent case studies through the use of the *Combinatorial Architecture* methodology. The case studies inquiry the effectiveness of the *Combinatorial Architecture* methodology as a support tool in the creation and transformation of urban atmospheres from two precise perspectives: the public art project for the NYC First Street Garden, transforming the atmosphere of an existing urban park in New York, and the Land Art proposal for the *Whirlers* wind turbine park, which was selected by UNESCO as an example of the possible creation of unprecedented forms of public spaces. The phase-based methodology described above explores classical architectural questions shared by the masters of modern architecture (Tiazzoldi, 2006)<sup>2</sup>, where the balance between qualitative and quantitative architecture attributes affects the relationship between measurable and non-measurable dimensions in architecture composition and urban form. This theme was previously presented in the case studies included in the Second International Congress on Ambiances,<sup>3</sup> specifically the project for a formal modulation for acoustic panels in a bridge (2009), the urban playground *Onion Pinch* (2009), and the *Pavilion Social Cave* (2011). Both case studies analyzed in this paper dwell on the principle that a *Combinatorial Architecture* methodology may be applicable retroactively and in new urban and architectural projects. This methodology is responsive to issues inherent to existing urban form and proposes solutions for architecture practice in new urban settings.

### *Case study 1: Ambiantal experiences and experiments for transforming the atmosphere in an urban NYC Park*

The first case study investigates how the combinatorial approach to architectural design can be applied to modulate pedestrian flows and create the notion of urban atmospheres in a metropolitan city park. Conceived in the context of a public art commission, the Instant Installation is a reconfigurable structure developed by the

2. <http://architettura.it/extended/20040612/>

3. <https://www.canadianarchitect.com/architecture/ambiances-in-action-at-the-canadian-centre-for-architecture/1001701089/>

author for the First Street Garden in New York City, a derelict building lot at 33 E. First Street in Manhattan converted into an open art space serving the Lower East Side community. Developed within the curatorial programming of Critical Practices FSG for the NYC Parks, the Instant Installation is part of an ongoing series of cultural programs in NYC First Parks to activate public space by engaging with emerging artists, architects, and community and cultural groups. Designed with a maze of coloured rubber wires, Instant Installation is a portable structure that can be twisted and anchored in different ways, achieving different spatial configurations in response to the specificity of a particular location and urban performance. The project is a second iteration of a first installation developed in the research lab of the Non-Linear Solutions Unit at Columbia University for a winning entry in the 2013 edition of the University of Memphis Art Museum Art Competition.

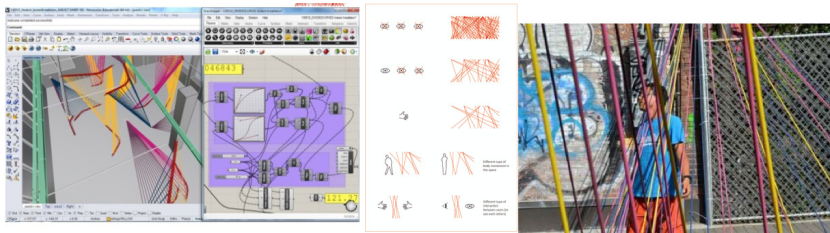
The case study of *Instant Installation* can be considered Ambient experimentation for making an urban atmosphere from the way it explores the idea of physical enclosure and its interaction with the citizens who experience it. *Instant Installation* was conceived as a portable piece of architecture with the capacity to regenerate, articulate, disrupt, and transform the pedestrian flow in a public space where it is laid out. The adaptive characteristics of the installation were tested in its capacity to produce different kinds of urban atmospheres in the First Street Garden Green Open I Art Space, which may be considered a 'real-life' testing platform for the *Combinatorial Architecture* methodology. First Street Green is an urban park with a "T" shape connecting two heterogeneous social groups: the upper middle class in the Soho neighborhood and the community homeless shelter on E First Street. The T-shaped form of the park blocks the visual connection between the two entrances of the park and creates an area of visual uncertainty. This factor gave the feeling of lack of security in the urban environment'. An initial site visit showed that this condition of uncertainty significantly reduced the number of people using the Soho entrance and enhanced the park's appropriation by the homeless population.

The *Combinatorial Architecture* approach to transform the urban atmosphere in the First Street Park addressed the question of how the manipulation of the measurable attributes of "visibility" and "accessibility" could affect the pedestrian flow across the park. When planning the architecture for the public art commission, the author revisited the three phases of the methodology previously described. These were applied first by referencing the creative reductionism phase in listing a series of measurable attributes for entities or building blocks that may be manipulated and reactivated, engaging with the combinatorial architectural capacity to adapt and physically respond to the different locations. This list of building blocks was defined by a set of wooden rails fabricated from a computer numeric control manufacturing process, a series of coloured rubber tubes, and metal anchoring rings. Among the attribute the density, the nesting geometry and layering of materials were conceived to affect and solicit curiosity and reactions from the public. In order to efficiently utilize the building blocks and attributes, these were associated with the use of a parametric design protocol defined in Rhinoceros Grasshopper plug-in. Their flexibility and reciprocity allowed for a change in the density of the material layers through the intertwining of rubber tubes and the moving and anchoring of the different rails. Once the first methodological phase was achieved through the association of the attributes of each building block (rails, tubes, and rings) to levels of material density, it was possible to initiate the second phase. At that point, the

creation of a new population of configurations enabled a change in transparency levels and accessibility to the structure in the park. The third and last phase or the “selection” phase of the combinatorial process identified which configuration responded more efficiently to the specific conditions inherent from the programmed requirements. During this phase, it is possible to identify single solutions that could respond to the performance parameters to make a series of urban atmospheres. The first solution was tested in the summer of 2014 on the occasion of the public event La Table Ronde (LTR), a roundtable series of discussions organized by the curatorial programming of Critical Practices CPI-FSG for NYC Parks. The Instant Installation was laid out in order to create a gathering forum for the discussion of contemporary social and cultural issues in public space. During the layout developed for the forum event, the Instant Installation was used as a space activator to engage and partially transform the flow dynamics of the citizens in the park. To further select, which solution and location would better, serve the forum structure, the installation was located and tested in different points of the park. The rails and rubber wires were located strategically, permitting the creation of different types of visual connections between the two park entrances (Houston Street in Soho and First Street in the East Village).



Figure 3. NYC First Street Garden, an urban park with a T-shaped perimeter connecting two heterogeneous social groups: the upper middle class in the Soho neighbourhood and the community homeless shelter on E First Street. (Images courtesy of the author)



Figures 4, 5, and 6: Instant Installation at NYC First Street Garden: The sequence of images represents the manipulation of the method’s attributes and building blocks in a set of data attributes and material properties. The workshop with the teenager students of the Bronx River Art Centre. (Images courtesy of the author)

A second solution was investigated in the creation of a participatory urban atmosphere during a community workshop. On August 2014, the initiative hosted a group of teenage students from the Bronx River Art Centre (BRAC) Summer Educational Programme. Rather than identifying specific solutions, the performative qualities of the installation structure were further adapted to motivate students’ participation. Students were asked to propose new configurations of the Instant Installation. Here the parametric design tool previously developed in the *Combinatorial Architecture* second phase (creation of a new population of configurations)

became a prompt for real-time experiment and rearrangement in which the students were asked to engage with the installation's attributes as building blocks (distance of the rail, distance between the lines, nesting of the lines, the density of the different units).

By combining different attributes and building blocks (spacing, distance, layers of material, position of the rails in relation of the main entrances, relative positions), the students explored how their direct participation in laying out the installation affected the making of urban atmospheres. The series of spatial configurations enabled each student proposal to affect the pedestrian flow in the park by varying the levels of each identified attribute. This experimentation enabled the students to test a combinatorial sequence of solutions in accord with their preference.

The process developed for this architectural installation enabled the BRAC students to better understand their own relationship with the public environment and become active participants in the creation of a reconfigurable urban atmosphere. This experience allowed for real-time testing of the *Combinatorial Architecture* methodology to enable the mapping of each configuration and its effects on the types of responses from the New Yorkers.

### *Case study 2: An active regeneration of a landfill for the creation of an unprecedented atmosphere*

The second case study continues to investigate how a combinatorial approach to architectural design fosters new forms of urban atmosphere. While the first case study focused on the adaptability of an architecture installation to modulate pedestrian flow in a metropolitan park, this example examines the regeneration of a landfill in a renewable energies landscape park. Conceived as a wind turbine park, the *Whirlers* create an unprecedented form of hybrid ambiance between public spaces and renewable energies plants. The design of the *Whirlers* was conceived as a three-dimensional grid of Darrieus turbines<sup>4</sup> (The *Whirler* turbine is designed along the logic of vertical-axis wind turbines with the main rotor shaft arranged vertically. That collect wind and transform it for perceptive energy production. Its capacity to generate unprecedented types of public spaces is supported in the application of the *Combinatorial Architecture* methodology to associate the physical and qualitative properties of a public space with the quality of a renewable energy park.

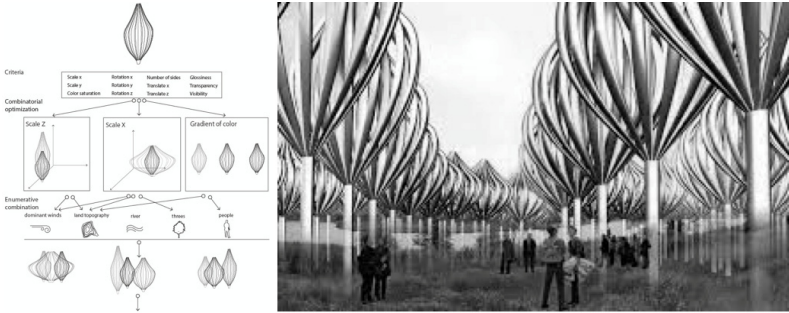
Similarly to the previous case study analysis, this paper examines how the *Whirlers* is the result of a *Combinatorial Architecture* methodology inspired by the *Combinatorial Architecture* approach. The three-phased approach (creative reductionism, creation of a new population of configurations, selection of the solutions fitting with the evaluation criteria) enables the adjustment and association of the physical and measurable spatial attributes scale, length, colour of wind turbines, to achieve a range of different public space typologies (with various thermal, chromatic, and density qualities) through the manipulation of rotational and relative distance values between specific building blocks (wind turbines).

During the first phase (creative reductionism), the turbines unit devices (building block) were qualified according to the *Combinatorial Architecture* method. The

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4. The Darrieus wind turbine is a type of vertical axis wind turbine (VAWT) used to generate electricity from the energy carried in the wind. The turbine consists of a number of curved aerofoil blades mounted on a vertical rotating shaft or framework. (...) This design of wind turbine was patented by Georges Jean Marie Darrieus, a French aeronautical engineer in 1931.

various heights and colours (attributes) could be scaled and distributed along a variable grid. In the second phase of the methodological process (creation of a new population of configurations), rotational factors were used as input to determine the orientation of the devices. In addition each device was scaled in different heights to maximize wind exploitation.



Figures 7 and 8: The different phases of the combinatorial method applied to the definition of a wind turbine population in the landscape (Images courtesy of the author)

Lastly, the third phase defined a solution where the grid of building blocks (wind turbines) was adapted to the forestry in the landscape and spaced in response to the topography of the site, the type of experience mixing. By combining the physical properties of two types of spaces, the *Combinatorial Architecture* method permitted the creation of a new spatial concept conceived as a whirling artificial forest, changing the visual and thermal perception of the land by combining natural and artificial elements. The resulting park is of an unprecedented form of ambiance in which more than 10,000 colorful turbines spin following the ground and wind direction, creating an inebriating visual experience ranging in color and scale to remind viewers of a spinning forest. In 2014, the *Whirlers* project was selected by UNESCO World Heritage as a special project to feature in the conference on renewable energies RENFORUS I RENISLA in El Hierro – UNESCO Biosphere Reserve (Canary Islands, Spain).<sup>5</sup> The *Whirlers* was recognized as an example of a project connecting qualitative and measurable properties such as a performative response to wind flows with qualitative and non-measurable qualities such as a level of ‘poetic’ and ‘inventiveness’ in creating a vision for a land artwork. The project was recognized for its capacity to connect renewable energies with a public environment.

## Conclusion

The analyses of the case studies *Instant Installation* and the *Whirlers* show how the *Combinatorial Architecture* methodology can respond to the problem of transforming the atmosphere in an existing urban context and foster the development of unprecedented forms of ambiances connecting public spaces with renewable energies. The method associating qualitative and quantitative data in urban and

5. RENISLA2014 is one of the actions in partnership with the RENFORUS Initiative (Renewable Energy Futures for UNESCO Sites) of UNESCO. It aims to promote the use of UNESCO sites (Biosphere Reserves and World Heritage Sites) as field observatories on the sustainable use of renewable energy sources to mitigate climate change and to enhance and apply the climate change knowledge base for building green societies.



architectural design processes addresses fundamental questions of modern architecture: the relationship among a rules-based architectural composition, urban planning, and the human dimension. The research results raise the question of the potential application of the methodology *Combinatorial Architecture* in territories in transformation for the creation of ambiances in developing countries in which the population has increased by more than thousand percent per year and in which the *in-situ* survey can no longer be the reference. The methodological challenges for the next steps of the research will be focused on the development of a critical approach to the rapid growth of the cities of tomorrow by investigating a specific case in new urban environments. The challenge will be to explore how a method-based procedure can foster an urban planning strategy to embed bottom-up and top-down architecture and urban design solutions to ultimately assess how the vision for a human habitat can incorporate both generative and transformative procedures in the making of an atmosphere.

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