Performative architecture as a guideline for transformation

Defense Line of Amsterdam

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Abstract. Performance as an architectural design paradigm has been emerging during the recent years. We have developed an understanding that we formalized as a taxonomy for performative architecture that considers performance from three points of view: health, safety and security performance; functional and efficiency performance; and psychological, social, cultural, and esthetic performance. This paper focuses on a design project that explores these ideas as a performative architecture proposal. The project focuses on the architectural transformation of the Defense Line of Amsterdam, 41 forts, as a green belt. This transformation considers a holistic approach of defining a general method and guideline. We developed a series of parametric models for the definition and generation of designs. The first model computes an urbanization level for each fort. Consequently, models are developed in 4 stages: regional design, urban design, building design, and production of a scale model, and these are applied in an iterative manner to reach design outcomes for the project.

Keywords. Performative architecture; performance evaluation; taxonomy; parametric modeling.

PERFORMATIVE ARCHITECTURE

Development of new instruments and methods contribute to a new understanding of the way buildings are imagined, constructed and experienced. Due to recent developments in technology, cultural theory and the emergence of sustainability as a defining socio economic issue, there is an increasing interest in performance as an architectural design paradigm (Kolarevic, 2005). The paradigmatic appeal of the performative in architecture lies precisely in the multiplicity of meanings associated with it; however, performance is still one of the least defined concepts in architecture.

Being performative is usually associated with sustainability and complex digital models analyzing the structural and environmental behavior of buildings. This limits performance to a merely technical interpretation (Menges and Hensel, 2008). Performative architecture must also consider other aspects, because architecture has always performed socially, semantically, ideologically, and in a basic manner as
a shelter (Hagan, 2008). Therefore, the question “what is architectural performance in the digital age” gains importance. Is this performance comparable to the performance of a machine or a theatrical performance (Leatherbarrow, 2005)? There is no single answer for this question because of the multiplicity of the meanings and connotations of the word performance (Oxman, 2009). Determining different performative aspects in a particular project and reconciling conflicting performance goals in a creative and effective way are key challenges in performative architecture.

Within the scope of this paper, performative architecture is considered as the shift in the orientation of architectural theory and practice from what the building is to what it does. Therefore, it defines the architectural object, not by how it appears, but rather by its capability of affecting, transforming and doing; in other words, by how it performs. The aim of performative architecture is to prevent clashing ideas between the performance aspects by optimization methods. Optimization should not be limited to a technical interpretation. If performative architecture is limited to simulation and evaluation, then there will not be much difference between performative architecture and engineering. Performative architecture should have the capability to generate. It uses digital generation and modification to search for design alternatives. The generated emergent effects of the architecture (on nature, site, people, climate and time) are analyzed both qualitatively and quantitatively in performative architecture.

In this paper we present an approach to performative architecture and its exemplification through a project: the architectural transformation of the Defense Line of Amsterdam.

**PERFORMANCE ASSESSMENT**

Building performance assessment is multidisciplinary and it has generated applied research that lacked a coherent theoretical framework until recently. We have developed a taxonomy to be used as a guideline while developing and assessing performative architecture models. The development of this taxonomy is based on a literature research on Building Performance Evaluation (BPE) and an analysis of selected buildings as case studies. The analysis of these case studies has been conducted in terms of project goals and the process to achieve these goals. The knowledge and experience gained from the literature and the analyses have been formalized in a taxonomy of criteria for performative architecture.

The first level of this taxonomy is based on an adaptation of the classical classification of qualities defined by Vitruvius. Firmitas has been interpreted as health, safety and security performance (branch 1), utilitas as functional and efficiency performance (branch 2), and venustas as psychological, social, cultural and aesthetic performance (branch 3) (Preiser and Vischer, 2005). Branch 1 pertains to building codes and life safety standards projects must comply with. Branch 2 refers to the state of the art knowledge about building types and systems. Branch 3 pertains to research based design guidelines, which are less codified, but nevertheless equally important for designers. These branches are further specialized in the taxonomy as sub-goals.

The application of a number of these sub-goals may interact and even conflict with each other, requiring resolution in order to be effective. Using this taxonomy, what causes architecture to be classified as performative is the correct selection of performances and relationships. Environmental performances could clash with economic performances, or aesthetic ones could clash with social ones. Defining the adequate geometrical relationships to prevent these conflicts is the main task of performative architecture. Especially, the parametrization of the Branch 3 aspects must be addressed by the design team when exploring the design solutions.

**ARCHITECTURAL TRANSFORMATION OF THE DEFENSE LINE OF AMSTERDAM**

We have developed a performative architecture proposal as a design project in order to explore and test these ideas. This project deals with performative architecture to address a model of design to
generate transformation alternatives for an actual design problem of Dutch Landscapes: the transformation of the Defense Line of Amsterdam, which involves the conservation of 41 forts, assigning them new functions and designing additions. The Defense Line of Amsterdam is a ring of fortifications around Amsterdam, constructed between 1880 and 1920, conceived as a logistical system in combination with the low lands, which can be flooded in wartime. The invention of the airplane and tank made the forts obsolete almost as soon as their construction was finished. The Defense Line was inscribed to the UNESCO World Heritage List in 1996 because of its historic value for all mankind. Moreover, the forts are important elements of the Dutch landscape for enriching the topography while demonstrating a unique historic example of defense and water management technology. Presently almost all forts remain in good condition.

The design of the forts is mainly reasoned to meet the requirements of the military function and they all consist of the same elements. These are: ring of water, glacis of muddy slope, front of the fortress covered with sand, fort, courtyard, bridge, shed and defense dike. The forts are designed as artificial hills for camouflage reasons. Owing to the fact that the front of the fortress is covered with sand, it is impossible to notice the fort from the outer side of the ring.

A few forts have been given new functions by private investigators. After 1996, privatization of forts gave way to charitable organizations. Currently the transformation of the Defense Line is an actual subject in The Netherlands. This transformation should not be understood as renovating the forts and assigning them new functions individually. The original concept and design of the Defense Line involves a holistic understanding; therefore, its transformation requires the definition of a general guideline rather than focusing on its parts separately. For this reason, performative architecture is used to define a guideline for the generation of alternatives for the collection of forts.

A century after the forts were constructed, many new relationships are created between forts, water, infrastructure and urban areas. The first step for transforming the Defense Line is to analyze these relationships. Concentration of infrastructure and urbanization affect the number of potential users, the scale of the transformation, and the size of needed additions for each fort. The definition of the guideline for the transformation is initiated by a parametric model that computes urbanization levels for the fort sites using the following inputs: waterlines, land transportation connections (rail lines and highways), urban areas, Schiphol airport noise level contours, green zones (forests, nature reserves and recreation areas), and green houses (Figure 1a). We have used parametric design using the Grasshopper® software as a medium for this exploration as a result of an inquiry into the state-of-art of computational tools for performative architecture.

The fundamental logic behind the parametric urban model is very simple: a surface populated with boxes whose height varies in relationship to an attractor point. These location of each box on the surface corresponds to a physical location in the area where the forts are located, and the height of the box corresponds to the urbanization level of that location as a combination of the inputs described above (Figure 1c). In order to achieve this, first, a surface that covers the region is created and divided into a grid. Then, the input data mentioned above is used to deform the height of the grid cells successively. Two factors are used to control the deformation: weight and area of influence. The designer assigns an importance to a specific input by selecting a weight for that input, which controls the height of the deformation of grid cells. Similarly, the area of influence of the specified input is determined by the designer (Figure 1b).

Computation of urbanization levels reveals that the sites of the 41 forts have great disparities. We developed a model in order to create a guideline for the transformation of the forts. This model, named ‘performative design model’, uses the performative
Figure 1
A diagrammatic summary of the process for the parametric urban model. a) different inputs to calculate the urban levels for the region of Defense Line These inputs are: waterlines, rail lines, highways, urban areas, Schiphol airport noise level contours, green zones (forests, nature reserves and recreation areas), and green houses; b) different values of weight and area of influence for different inputs; c) the output of the parametric urban model.
architecture taxonomy as a guideline and consists of a series of parametric models through the design stages. The performative design model illustrates the following emergent effects of performative architecture:

• combining developing technologies with cultural heritage;
• using capabilities of affecting, transforming and doing to define additions to the forts (an element of the cultural heritage);
• disclosing functionality and reasoning of a building through the form;
• automatically generating different design alternatives for different sites;
• enabling quantitative and qualitative analysis through digital and physical models;
• producing creative and effective design solutions;
• producing new effects that transform culture.

The performative design model for the transformation is articulated in four stages, parallel to the stages of a conventional design process. These stages are: regional design (1/50.000); urban design (1/1.000); building design (1/200); and the production of scale models; therefore, the model provides design support from conceptual stage until production of scale prototypes in an iterative manner.

Stage 1: Regional Design
The first input for the model is the selection of a site. The urbanization level of the site defines the scale of architectural transformation. The defense Line is transformed into a green belt around Amsterdam. The forts are transformed into nature parks and botanical gardens. The forts within the sites with high urban levels will be selected as transit points. They will become official visitor centers and all the forts will be connected by boat tours, biking and hiking trails. Guided tours take the visitors through this green belt around Amsterdam. The forts that host the visitor centers will provide a wider range of activities. They will be used by two groups of users: those that use the fort as a transfer area that connects the urban elements within the site, and those that aim to do sightseeing and spend time around the fort. The forts with low urbanization values will be used by a small number of users such as locals living in neighborhood and biking or hiking trail groups.

The simplest functions are the ones that provide space for basic human activities such as: walk, relax, sit, climb, play, picnic, eat, talk, swim and sunbathe. Complex functions hold cultural, commercial and educational activities. The botanical displays in the interior of the forts educate visitors about the region's flora. They provide workshop spaces where visitors can experience and learn how to grow plants or places for presentations to increase environmental awareness. The complexity of the function defines the size of the addition needed. For basic activities, the additions can be urban furniture, a floor or a roof structure. For instance, some structures provide shade and shelter, while some only provide suitable seating areas. Closed spaces are needed only for more complex functions, which can also be used to create suitable spaces for what are, basically, greenhouses or the compartmentalization of nature by humans.

The output from the urbanization level computation is processed as the input of the definition of complexity of the addition and required area (Figure 2). The final step of this stage is the generation of masses to meet new functional requirements.

Stage 2: Urban Design
The second stage of the performative model consists of two levels of independent parametric investigation. The first one concerns the definition of the relationship between the fort and the addition. The second one concerns the connections between elements of the site (the ring of water, the front fortress which is covered with sand, fortress, courtyard, bridge, shed, and defense dike) and the urban environment. The elements of the urban environment are transit points (train stop, bus top, road, car park, marina, etc.), urbanized areas (residential areas, industrial areas, greenhouses, etc.), and nature
zones (water bodies, forests, grasslands and micro-climates). Elements of the site and urban nature are both variables for the connections.

The relationship between the fort, addition and connections between elements of the site and urban environment are parametrically independent. However, in real life they need to coincide with each other. For the success of the transformation the addition must provide the needed connections between elements and desired relationship to the fort. Definitions in levels 1 and 2 of this stage act as attractors for the masses which were generated in the first stage of the performative model. Different configurations of the needed volumes are created as an output of this stage (Figure 3).

This stage of the performative model enables generation of designs having different relationships to the original structure. Dissimilar architectural points of views are created regarding the conservation of forts. The production of digital and physical models (in the final stage of the model) allows the quantitative and qualitative analysis of the different configurations. Due to this, the performative model promises success for the conservation of this UNESCO heritage site.

Stage 3: Building Design
The camouflage character of the forts has been very inspirational for the initial design ideas of this project. Accordingly, the additional buildings are interpreted as deformed stripes which resemble artificial hills similar to the forts. These continuous stripes are obtained from catenary arches which define the space for the required functions. Primarily catenary

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Figure 2
A diagrammatic summary of the process for Stage 1: positions of forts, inputs for computation of urbanization levels, urbanization level of site, complexity of functions that corresponds the urbanization value of site, bubble diagram of program elements and relationships between them.
Arches define compartmentalization of nature and function as elements that let sunlight in or provide shadow during specific times. To achieve these elements two parametric models have been defined for the building design stage. The first model computes catenary arches; the second one computes sunlight angles according to time and date. The alterations in the hierarchical structure of the performative model are possible by defining new dependencies between levels 1 and 2 of this stage (Figure 4).

\[ y = a \cosh \left( \frac{x}{a} \right) \]  

Figure 3
A diagrammatic summary of the process for Stage 2: definition of the relationships between the fort and addition: connections between elements of the site and the urban environment, reconfiguration of masses according to attractors.

The catenary equation (1) is used to obtain curves for the idealized arch. The first input for the parametric model for a catenary arch is assigning two points for maximum and minimum values in x axis to control the position of supports. Then, the pole position controls the minimum value in the y axis, which is chain length. The input named as steps is the number of points that are computed according to the catenary equation. The increase in the number of steps brings about more accurate results.

A lot of similar parametric models can be found online for the definition of catenary arches; however, none of these are adequate to achieve continuous deformed stripes from catenary arches. Therefore, this stage of the performative model must go beyond the computation of the form of a chain, which
Figure 4
A diagrammatic summary of the process for Stage 3.
is supported by its two ends and acted on only by its own weight. The interdependent variables of a, x, and y must be fed parametrically into the performative model.

Level 2 of this stage consists of computing sunlight angles according to changing time and location in order to generate needed spaces of the greenhouse according to their sunlight needs. The computed sunlight angles are not used only for analysis. Along with the catenary arches, they are the generative factor of the form of the addition for the fortress. The output vectors of this model are matched with the categorization of plants according to their sunlight needs. The locations of these matches define the voids of the form that lets sunlight inside, and the catenary arches define the solid parts of the form which works as a structural system.

Stage 4: Production of a Scale Model
Deriving values for the attributes in the first three stages of the model results in a generated form for the addition to the selected site of Defense Line of Amsterdam. The final stage is the conversion of this 3D model to the 2D files for the CNC cutter. This parametric definition enables production of physical models from 1/1000 to 1/200 scale. In each of these scales the presentation requires different levels of detailing. Before conversion to 2D, some preparatory steps are necessary according to the scale of the model. After these final modifications to the 3D model, the contouring of the form through 2D sections can be done. The basic parameters for contouring are scale, angle and spacing. Scale defines the desired scale of the physical model. Angle defines the rotation angle of the orthographic cut planes to the reference surface. Spacing defines the uniform distance between the sections. The contouring for each stripe must consist of the sections that are parallel to the stripe.

Production of scale models does not have to be the last stage of the performative model. 1/1000 scale is proper to visualize the results of previous stages. On the other hand, 1/500 and especially 1/200 scales are proper for investigating compatibility with the surroundings and relationship with existing elements of the site. If the results are not favored, the designer can go to the parameterization stage to change rules, relationships between rules, and parameters of the attributes. Therefore, this is an iterative process.

CONCLUSIONS
After the definition of design stages, the effort is moved directly to two other levels of the design: one is the parameterization process, preliminary to the computational generation of alternative solutions; the other is the selection process among the large set of generated instances. Parameterization
is the fundamental step of modeling in order to exploit the potential and advantages offered by parametric modeling. It is the determination of attributes (two kinds: dependent and independent) and the rules they are subject to follow. Parameterization describes the dependency chain used in the model as a hierarchical structure. The selection and definition of the interrelations during the earlier structuring of the model are set according to the performance criteria, which were established after the regional and urban analysis done for the Defense Line.

It is possible to computationally generate an infinite number of alternative design solutions, but this potential becomes useless if it is not associated with meaningful control, categorization and selection processes. A performative model is convenient within this scope since the designer is the decision maker in every stage of the design, where stages are defined as modules corresponding to different performances related to design. The design exercise that is presented in this paper is considered ‘performative’ because it considers performance as both quantitative and qualitative performance. Preferably, these can be measured and alternatives can be assessed through comparison of these measurements. However, performance of qualities, such as esthetics or certain spatial and architectural qualities, cannot always be objectively measured and the designer’s judgment needs to have a place in the decision process as well. This makes it performative architecture as opposed to engineering.

REFERENCES