Rethinking computational models for user participation in design

Theodora Vardouli
Massachusetts Institute of Technology, USA
http://architecture.mit.edu/student/theodora-vardouli
thvard@mit.edu

Abstract. In this paper I identify the “infrastructure model” as the predominant approach to computationally mediated participatory design from the 1960s until the present, and discuss its history, conceptual underpinnings, and limitations. As case studies for this analysis, I use the French-based architect Yona Friedman’s and the MIT Architecture Machine Group’s 1970s proposals for participatory design computational systems. I employ the polysemic notion of “performance” to interrogate the two systems in three levels: What rationale supports the authors’ claims that in order for design to well perform for its future users, it should be performed by them? What computational models are developed to enable users to perform their own designs? How can performance, as an intuitive, improvisational process, be used to criticize the traditional models of computation in design participation and devise new computational agendas?

Keywords. Participatory architecture; computer-aided participatory design; infrastructure model; improvisational performance; perceptual computation.

THE “INFRASTRUCTURE MODEL” OF PARTICIPATORY DESIGN

In the 1960s a now-familiar idea started echoing in the world of architecture and planning: professional designers should relinquish control over decision-making and implicate the end-users in the shaping of their living settings. Boisterous voices from within the design disciplines in the United States and in Europe, criticized professional designers for being unable to respond to the growing complexities of the built environment, and therefore resorting to statistical generalizations, which suppressed the particularities of their designs’ future inhabitants. User participation in design emerged as an alternative to a malformed and inefficient professionalism, counterpoising the argument that in order for design to be performative for its end-users, then it needs to be performed by its end-users.

Fifty years later, the rhetoric of the user-as-designer is being reinvigorated in architecture and planning, under the influence of current cyber-cultural discussions of “democratization” and the potentials of new design and fabrication technologies. Numerous initiatives in research and practice (e.g. Open Source Building Alliance [1], Home Genome Project [2], Blu Homes [3], etc.) explore methods and techniques in order to facilitate the participation of non-experts in the design of their living environments. However, the question of how much agency the non-expert future inhabitants actually have in
this process persists and offers grounds for critique
to the evangelisms of user empowerment and partici-
patation. The question of who performs the design,
the future inhabitant, the computational tool, or the
toolmaker, remains a difficult conceptual and practi-
cal problem.

This paper looks back into early computational
models of participatory design in order to historically
contextualize and critique a persistent approach
to non-expert participation in design from the
1960s until the present. This approach will be hereby
referred to as the “infrastructure model” (Vardouli,
2012). The “infrastructure model” denotes an alleg-
edly neutral and non-defining standardized frame-
work, within which the end-users produce person-
alized infills, usually with the aid of computational
tools that perform combinative operations within
the infrastructure.

This model is currently the predominant way of
thinking about participatory design platforms. The
so-called “configurators”, also used for the mass-
customization of consumer products such as auto-
mobiles or clothing, are the most usual commercial
expression of computer-aided participatory design
ideas in housing. The “configurators” guide the end-
users through lists of components, for example in-
terior partitions, openings, finishes etc., which fill-in
standardized structural frames to produce a person-
alized dwelling. The fatigue caused by the sequenc-
es of choices and the lack of design expertise by the
end-users, motivated the recent counterproposal
of the so-called “design recommendation engines”,
developed as part of the Home Genome Project of
the Changing Places Group at the MIT Media Lab.
The “recommendation engines” employ machine-
learning algorithms to model the end-user’s prefer-
ences and propose personalized architectural solu-
tions. These algorithms automate the “configurator”
process, making informed guesses about the infill
elements rather than prompting the end-user mak-
ing these choices.

Given the persistence and prevalence of the
“infrastructure model” in computationally mediated
participatory design, it is timely to ask if it adequate-
ly delivers the vision of giving the future inhabitants
agency in the design of their living settings. Moti-
vated by this question, I investigate aspects of the
history of the “infrastructure model’s” emergence in
participatory design, identify its limitations, and pro-
vide the ground to critically evaluate it and theorize
alternatives.

Two early examples: Yona Friedman’s and
the Architecture Machine Group’s participa-
tory infrastructures
In this paper I trace the origins of the “infrastructure
model” through a comparative analysis of two early
eamples of computer-aided participatory design.
The first example is the FLATWRITER, an imaginary
machine described in the book Pour Une Architec-
ture Scientifique, by the French-based architect Yona
Friedman (1971). The book was published in the
United States in 1975 under the title Toward A Scien-
tific Architecture, which I will hereby use when refer-
ning to it. The second example is the Design Ampli-
ifier, a computer-aided participatory design prototype
discussed in the book Soft Architecture Machines,
written by the head of the MIT Architecture Machine
Group, Nicholas Negroponte (1975). The Design Am-
plifier builds on an earlier proposal by the Architec-
ture Machine Group to the National Science Founda-
tion (NSF), entitled Computer Aids to Participatory
Architecture (Groisser and Negroponte, 1972).

I use the concept of “performance”, with its nu-
anced meanings, to set three axes for the discussion
of Friedman’s and the Architecture Machine Group’s
source materials from the perspective of the authors’
intentions, the authors’ implementations, and the
critique of misalignments between the two. In the
first section of the paper entitled “Arguing for Perfor-
ance”, I identify how the authors lay the claim that
the implication of the end-user in the design process
is a precondition for the production of well-perform-
ing designs. In the second section, “Implementing
Performance”, I analyse Friedman’s and the Architec-
ture Machine Group’s computational implementa-
tions of their participatory design systems and the
role of the “infrastructure model” in their epistemo-
logical, theoretical, and computational propositions. In the third and final section, “Seeking Performance”, I criticize the “infrastructure model” of participatory design for being entrapped in a combinatorial, linguistic conception of design, which permits limited creative agency to its users. In this critique, I use the notion of performance as a spontaneous, fluid, and improvisational process to rethink the requirements and desirable characteristics of a computationally mediated participatory design process. Drawing inspiration from the theoretical propositions of George Stiny and James Gips’ (1972) shape grammars, as a dynamic and perceptual model of computation, I conclude with a speculation on alternative conceptions of the participatory design enterprise.

ARGUING FOR PERFORMANCE: WHO SHOULD PERFORM THE DESIGN?

Yona Friedman: Programming the Spatial City

In 1956 Yona Friedman found himself in the 10th International Congress of Modern Architecture (CIAM) where he heard Team X’s criticism against the Modern Movement’s functionalist reductionism. The Team X called for an association of the urban and domestic scales in a relational structure centred on the human inhabitant. Disillusioned from the geometry-centric modernist conception of and struck by the realization that the average man is a fictive entity, Yona Friedman made mobility, freedom to choose and freedom to change one’s living environment, the main tenet of his architectural theories. In his first manifesto, entitled Mobile Architecture, he rejected pseudo-theories produced by architects to justify their own preferences, and called for a new general theory of architecture, “stemming from the public domain” and “underpinning all personal hypotheses” (Friedman, 1958). The architectural expression of this manifesto was the Spatial City (1958-59), a space frame standing on pillars which provided for structural stability, water, electricity, sewage etc., in which the inhabitants created ephemeral enclosures with light, non-structural elements. This architectural proposal was one of the first physical versions of the “infrastructure model”, where a standardized physical frame of high technology absorbed all necessary structural and functional constraints and offered the non-expert future inhabitants of the city the freedom to configure and reconfigure their living settings.

Although the formal aspects of Yona Friedman’s crystalline megastructure were highly impactful for the 1960s so-called radical architectural scene, Yona Friedman (1971) insisted that his main intention was a programmatic, and not a formal, renewal for architecture and planning. In the mid-1960s, after having provided a plateau for self-planning and self-construction, Yona Friedman’s interests started shifting toward the devising of a theory which would facilitate these processes. This methodological shift was influenced by his under-discussed expeditions in the United States, where he spent time as visiting faculty or researcher in institutions such as MIT, Harvard, UCLA, Princeton, and the University of Michigan in Ann Arbour. A first draft of Toward a Scientific Architecture was written in 1964 in the University of Michigan, to serve as a textbook for Yona Friedman’s class (Friedman, 2012). The book is mainly epistemological in content, and discusses the ways in which architecture can be remodelled as a teachable discipline, through the establishment of a new informational process between future inhabitants and their spaces of living.

Toward a Scientific Architecture can be read as the operational manual of the Spatial City, which complements the physical infrastructure of the space grid, with the immaterial infrastructure of the graph as a calculable representation of the structure of space. Friedman articulates a system of axioms and methods, which aim to remedy two “informational short circuits” (1971), which he observes in architectural processes. The first is related to the architect’s handling of the amount and complexity of information involved in large architectural projects and the second refers to the adjustment of the building to the shifting needs and desires of its future users. According to Friedman the complexity of the build-
ing projects and the large number of users who are stakeholders in the process, is unmanageable by the architect. The response to this “jammed circuit” is the invention of a fictive entity, the “average user”, who represents the statistical means of the largely diverse body of future users. The figure of the “average user” replaces the informational “jamming” with a “broken circuit”, where the architect’s design decisions are made to accommodate a non-existent entity instead of the “real” users. As I will discuss in the next section, the main technical apparatus in Friedman’s efforts to remedy this problem are calculations with graph theoretical representations of space, which he confesses to have largely adopted from his interactions with the mathematician Frank Horary, who was at the time also teaching at the University of Michigan, and who is considered one of the fathers and enthusiasts of graph theory.

Nicholas Negroponte: Soft Architecture Machines for Computer-Aided Participatory Design
In 1967 Nicholas Negroponte, still a student in the Department of Architecture, picked Yona Friedman up from the airport of Boston to accompany him at MIT, where he was invited for a lecture. In his introduction to the English version of Toward a Scientific Architecture, Negroponte (1975) admits having been impressed by Yona Friedman’s soft-spoken but potent argument that the end-users of a space should perform its design, as they are the ones who bear the risk of failure. One year after this incident, Nicholas Negroponte founded the Architecture Machine Group in the MIT Department of Mechanical Engineering, one of the first groups to systematically explore the intersections between computers and the creative aspects of design. Five years later, from 1973 to 1975, Yona Friedman would participate in one of the Architecture Machine Group projects, entitled Architecture-by-Yourself.

Influenced by the invention of time sharing and the recent advances in graphical user interfaces, pioneered by Ivan Sutherland’s first computer-aided design program at MIT, the Architecture Machine Group re-imagined computers as personalized, accessible technologies, enhancing human creative capacity, and set off to dissolve the idea that the computer was a tool for the “military-industrial complex only” (Negroponte, 1975). Computer-aided design offered a productive ground for the exploration of the tensions and potentials of a partnership between the human creative mind and calculating machinery. In 1970s Nicholas Negroponte collected and published these ideas in The Architecture Machine: Toward a More Human Environment. Inspired by the idea of “man-computer symbiosis”, as framed in JCR Licklider’s (1960) homonymous article, and by the visions and prospects of Artificial Intelligence, Nicholas Negroponte envisioned a computer-aided design system, an architecture machine, which would decisively improve the urban condition by guiding the designers’ decision making according to complex sets of local and global criteria, which would have otherwise been ignored by the designer.

Nicholas Negroponte’s personal acquaintance with Yona Friedman, who in the 1960s, had engaged in the mathematization and systematization of his radical proposals for design democratization and self-planning, as well as the influence from the growing popularity of participatory design in the United States in the context of the civil rights movement, led the Architecture Machine Group to a more radical version of the architecture machine: one that eliminated the architect and empowered non-expert users to shape their own living environment. The Architecture Machine Group’s proposal to the NSF in 1971, and later in Soft Architecture Machines, propose an architectural “do-it-yourselfism” that removes the professional (middleman) from architectural processes and gives the inhabitants full control of the design of their own environment (Negroponte, 1975).

A significant portion of the texts is dedicated on a discussion of the specific interactional and computational characteristics of the computer-aids to participatory architecture, so as to give full agency to the non-expert users and allow them to freely perform their individual choices, unconstrained by
the assumptions of the system’s designers. In other words, the Architecture Machine Group posed the challenge of a computational system, designed to facilitate the production of personalized architectural designs by their future inhabitants, without distorting their desires or personal hypotheses. This vision is reminiscent of Yona Friedman’s exploration of a non-paternalistic system in *Toward a Scientific Architecture*.

Yona Friedman and the Architecture Machine Group framed the proposition that the design of socially and ecologically performative environments could only be performed by their future inhabitants and, as I will show in the next section, proposed material and immaterial infrastructures as a way to deliver their vision. A closer look in the internal workings and the technicalities of their systems will expose the epistemological and cultural assumptions that support the choice of the “infrastructure model”, and offer a ground for their critique.

**IMPLEMENTING PERFORMANCE: WHO PERFORMS THE DESIGN?**

**An infrastructure for Objectivity: The FLATWRITER**

Friedman (1971) wrote *Toward A Scientific Architecture* in response to the arbitrary choices and the tricks of the trade of professional architects. He sought to establish architecture as a scientific, teachable discipline based on an objective framework of well-defined solutions, capable of accommodating all possible intuitive choices. In his book, Friedman defines “objective” systems as systems where the descriptions are communicable and transferrable as instructions regardless of contextual differences or the subjectivity of the observer. “Intuitive” systems, on the other hand, are systems where descriptions are based on symbols and codes, which are essentially context dependent and open to interpretation (Friedman, 1971).

Friedman’s “scientific architecture” is a remodelled architectural process, where the architect constructs complete repertoires (combinatorial lists), which hold all the possible solutions (spatial configurations) to a problem (the connection of n spaces). These solutions are represented as n planar graphs, connected and labelled, which can be isomorphically mapped to a real design. In Friedman’s mapping, the points of the graph correspond to spatial enclosures, the links to correspond to accesses, and the labels denote functional or formal differentiation. The advantage of the graph theoretical representation, apart from its alleged realism, is the ability to extract different metrics and numerical evaluations for each graph (spatial configuration). These metrics calculate the adequacy of each configuration, according to the future user’s living habits, and issue “warnings” which inform the user and the community about the implications of each design decision (Figure 1).

In *Towards a Scientific Architecture* Friedman proposed a machine for the implementation of his new architectural process. The FLATWRITER is an imaginary machine for participatory design, which takes the position of the architect in constructing the “repertoire” of architectural solutions for a given problem; the machine creates a complete combinatorial list of linkages, which can be populated with labels suggested by the users and formalized in a personalized “keyboard”. In the first loop the users are exposed with all combinatorial possibilities and is warned about the results of each linkage, after inputting their living habits for a specific period of time. After the configuration has been chosen the users are presented with a diagram of the infrastructure, where they can occupy the “free” areas. Every planning selection is accompanied by a second warning issued this time to the community and corresponding to urban criteria, also expressed by a means of “effort”. If no conflicts occur then the user acquires an instant building permit and realizes the construction.

The route to architectural democracy for Yona Friedman (1975) is the invention of a common, universal, and inter-personal “language” which replaces architectural idioms. The representation of the design problem as a graph appeared a well-fitting
solution, as it separates the intra-personal and the inter-personal factors of the design. The graph represented constraint-generating interpersonal and communicable structures, while the labelling accommodated the elusive, intra-personal desires and meanings of the future inhabitants.

**Infrastructure for Subjectivity: The Design Amplifier**

Opposite to Friedman's aspirations for science and objectivity, Negroponte and the Architecture Machine Group posited heuristics and subjectivity as the fundamental requirements of their participatory design system. As Negroponte wrote in *Soft Architecture Machines*, architecture is based on missing metaphors and meaning. This inevitably idiomatic, personal, and metaphorical character condemns any general theory of architecture to failure. Instead of a universal axiomatic of architecture, Negroponte advocated for a system that interacts with the users in a conversational manner and adapts to their idiosyncrasies using heuristics and rules of thumb.

The Architecture Machine Group proposal aimed to provide the means for novices to interact with a low-cost satellite computing facility in order to design their physical surroundings. The Design Amplifier, a version of the Architecture Machine Group's speculations on participatory architecture machines, takes linguistic and graphical input from the non-expert user and uses sketch recognition algorithms to represent the structure of the user's sketches (spaces and connections between spaces) with planar connected graphs. These graphs are used as the basic spatial structure to generate design possibilities according to a series of criteria, either hardwired in the machine or inferred from its interaction with the user. In this system users sketch elements, name and label them in order to graphically express their desires, in a personal, intuitive way. The machine, carrying an embedded architec-
tural knowledge (expert system) asks for clarifications, "argues" with the users, urges them to reflect on their own behaviours and proposes personalized designs. The non-expert user visually evaluates these recommendations in a conversational feedback loop (Figure 2).

**Analysis: Infrastructural Optimism and its discontents**

In Friedman's proposal the "infrastructure model", the "objective" as a framework for the "intuitive", finds an epistemological, computational, and physical expression. From an epistemological perspective, in Toward a Scientific Architecture Friedman proposes a separation of the "objective" from the "intuitive" part of the architecture and planning discipline. In this division, the architect/planner is assigned with the role of an objective expert, who produces frameworks of action (infrastructures) for the future users through sets of transparent and mechanical operations. These infrastructures are either physical (the *Spatial City*) or computational (the combinatorial list of n graphs). For Friedman the systematic subdivision of space through the *Spatial City*'s structural grid captures the structure of space. As he writes in Toward a Scientific Architecture, the *Spatial City* is in fact a saturated graph, which means that it can contain all possible spatial structures simply as its sub-graphs. The "objective" role of the architect/planner in this system is the production of these sub-graphs through a process of simple combinatory and some elementary graph calculations for the issuance of the "warnings" to the different end-users. In Friedman's proposal, the operations of the architect/planner are fully mechanized, to the extent that a computer, the FLATWRITER, can replace them. The future user operates on top of this objective level and represents spontaneity, intuition, and creativity. It is up to him/her to select a spatial structure from the list of graph combinations and label its nodes, thus giv-
ing formal characteristics and personal meanings to what until then is a featureless spatial abstraction.

Besides its emphasis on fluidity and intuition the Architecture Machine Group’s proposal exemplifies another version of the “infrastructure model”, in an interactional, conceptual, and a computational level. Similarly to Yona Friedman’s proposal, the architecture machine represents “competence” while the end-user represents “intuition” (Negroponte, 1975). In *Soft Architecture Machines*, Nicholas Negroponte (1975) writes about to a form of immaterial “infrastructure”. In a conceptual level this denotes a set of objective global constraints and criteria, which transform and are transformed by local desires. From a computational perspective, the internal workings of the machine also follow a structural logic. The non-expert user’s sketch is mapped into an isomorphic spatial structure, which is recombined by the machine to produce design alternatives. These structural representations of the sketches are used as “realistic” mathematical surrogates of the non-expert user’s intuitive design, on the basis of which the machine performs calculations and selects the optimal solutions for each user.

Let us return to this section’s main question: *Who performs the design?* Friedman characterizes his system as “non-paternalistic”, claiming that the future inhabitant is granted complete agency in the process of design. Having mechanized and automated the operations of the expert (architect/planner or machine) and having permitted subjectivity solely to the future user, Friedman claims to have addressed the problem of authorship. The graphs are meaningless abstractions unless the future inhabitant makes them concrete. Nicholas Negroponte (1975) lays a similar claim to “non-paternalism”, which he bases on the graph’s immutability allowing for isomorphic translations between the future inhabitant’s sketched intentions and the machine’s mathematical calculations. Gravitating toward scientific objectivity and transparency in Friedman’s case, and toward an undistorted mathematization of subjectivity in the Architecture Machine Group’s case, the “infrastructure model” divides and streamlines a quantifiable and controllable base of design, with an intuitive and improvisational superstructure. By operating as a controllable infrastructure of meaning, the representation of the graph allows the authors to reconcile their modernist impulses for order and control with their ethical discussions of democracy and non-paternalism (Vardouli, 2012).

**SEEKING PERFORMANCE: WHAT IS LEFT OUT?**

The aspiration of the *Spatial City* was to provide a plateau for urban extemporaneity, a city in constant flux based on its inhabitants ever-changing desires and patterns of life. It was a similarly fluid and improvisational process that the Architecture Machine Group sought to introduce in the interaction between a novice designer and the participatory architecture machine. In order to enable improvisation both systems needed to account for change and emergence. Is the “infrastructure model” an adequate computational model for the dynamic actions that it seeks to facilitate?

On this level the two proposals fall victims to a modernist impulse: in their effort to design for the unpredictable, they constrain and restrict it. The nodes of the graph are discrete entities, which are defined at the beginning of the process and constitute the design problem definition. The labels of the nodes, which represent the user preferences, are linguistic specifications overlaid on the structure and not interacting with its calculations. The design therefore stops before it even begins: once the design problem has been defined and represented, the solution already exists, as one possibility of combination between the nodes and the labels of the graph. The freedom of the future users is restricted to a choice between these possibilities, presented as a full list in Friedman’s case, or as single recommendations in the case of the Architecture Machine Group. The “infrastructure model” excludes the possibility of radical restructuring of the design problem during the process, therefore excluding unpredictability and emergence, which are key in creative design processes. The two systems suppress time
and impose a decisionist model of participation to the future users, making extemporaneity an unfulfilled vision.

In designing for the unpredictable, can one devise a system where there are rules without structure and where the pieces are not known in advance? Can one design computational systems, which allow users to participate in design in a fluid, experiential way, transcending segmentations, hierarchies and predefined ontologies and asserting design as extemporaneous performance? In the quest for new computational avenues, ideas on alternative models of computation priming ambiguity and interpretation are valuable computational allies that can help us rethink design participation as improvisational performance. Attempting to theorize an alternative approach, I conclude this critical analysis of the “infrastructure model” with a promising computational counterpoint. Almost contemporaneously with Yona Friedman’s or the Architecture Machine Group’s explorations, George Stiny and James Gips (1972) proposed shape grammars, a computational theory which rejects the division between deep structures and surface meaning. Shape grammars follow the logic of rule-based transformations, where the elements on which the rules are applied are not labelled or defined in advance but are picked extemporaneously, while acting on the working scene. This intra-personal seeing, doing, and forgetting thinking (Vardouli, 2012) to always start fresh, offers a compelling theoretical model for rethinking participatory processes, which implicate multiple subjectivities and ways of thinking. Opposite to Friedman’s or the Architecture Machine Group’s quest for inter-subjective, communicable representations and common ways of seeing, shape grammars build off the erratic nature of vision and the inevitable elusiveness of communication, and seek to accommodate different and unpredictable ways of seeing. The constant perceptual restructuring of the design process and the assignment of control to subjectivity, is epistemologically and conceptually orthogonal to the “infrastructure model.”

THINKING BEYOND THE INFRASTRUCTURE?
In this paper I used two historical examples, which exemplify a pervasive model of computationally mediated participatory design, first stated in the 1960s and persistent until the present. I called this model the “infrastructure model” to refer to a way of thinking about participatory design, where the parts of design that require expertise and objectivity are separated from the ones that require intuition. Through the analysis and comparison of Yona Friedman’s and the Architecture Machine Group’s early proposals and theoretical explorations, I sought to expose the logic and conceptual underpinnings of this model, in order to theoretically analyse and critique it. Using the notion of “performance” as the main axis of my analysis, I interrogated the two proposals in three levels: intentions, implementations, and misalignments between the two. I approached to the first level through a historical overview of the different historical and cultural contexts that motivated Yona Friedman and the Architecture Machine Group to develop their participatory design systems in France and in the United States respectively. In doing so, I traced a climate reminiscent of current phenomena: a cultural climate promoting individualism and personalization, new technological possibilities ranging from novel structural systems to the emergence of the computer, and a demand for personally responsive, socially and ecologically performative environments. In a second level, I described the two proposals and critically analysed their implicit hypotheses and assumptions. I identified a structuralist optimism in both authors, and analysed the discursive role of their computational representations in their proposals. In the last part of the paper, I discussed the limitations of the infrastructure model in fulfilling the authors’ vision of an improvisational participatory process, and suggested shape grammars as offering an alternative theoretical proposition for extemporaneously performative participation. Performative, action-oriented participation counters the a-temporal logic of structure and offers potentials for rethinking the role of
computation in participatory design, at a time when user-centric design and collective authorship comes back to the architectural actuality.

REFERENCES
Friedman, Y 1971, Pour Une Architecture Scientifique, Belfond, Paris.
Groisser, LB and Negroponte, N 1972, Computer aids to participatory architecture, Massachusetts Institute of Technology, Cambridge, MA.
Vardouli, T 2012, Design-for-empowerment-for-design: computational structures for design democratization (Thesis), Massachusetts Institute of Technology, Cambridge MA.