Scale and Complexity

Multi-layered, multi-scalar agent networks in time-based urban design

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Introduction or A Question of Time

Urban design, perhaps even more than architecture, is a time-dependent discipline. With its multi-layered complexities, from individual buildings to entire regions, decisions made at one level, that may not show effect immediately, may prove to have disastrous consequences further down the line. The need to incorporate time-based simulations in urban modeling, and the demand for a means of evaluating the changes have led to explorations with multi-agent systems in computation that allow for decisions to be decentralized. From the first basic rule-based system of Conway's Game of Life [1] to recent urban simulations developed at institutions like the ETH Zurich [2], or UCL CASA [3], these programs synthesize the various exigencies into complex simulations so that the designer may make informed decisions. It is however not enough to simply use parametrics in urban design. Rules or desires implemented at one scale may not apply to another, while isolating each scalar layer for independent study reverts to the disjunctive and shortsighted practices of past planning decisions. Central to current parametric research in urban design is the need to deal with multiple scales of urbanism with specific intelligence that can then feed back into the collective system: a networked parametric environment.

This paper will present the results from a city-generator developed in Processing using multi-agent systems that operate interactively at various scales. These agents, while having specific localized intelligence, are also able to react to changes happening at other scales of the city while maintaining their respective goals and desires within the development. Rather than implement one set of rules that governs all scales, or only focus on one scale of study, the multi-layered implementation of agents simulates more closely the complexity of urban environments and the convergence of diverse and even conflicting sets of criteria. We aim to address the following key issues in the use of multi-agent systems for contemporary urban design:

1. the use of multi-layered agent systems as a creative (not just representational) urban design tool;
2. the potentials for an adaptable yet project specific collaborative environment;
3. and the projected capacities of the technology in addressing the changing role of urban design.

Networked agent systems as creative urban design tools

When applied to the urban scale, networked parametric thinking demands that we consider our cities as ecologies. The network-based behavior of a genetic algorithm begins to simulate the complex relationships of urban life where changes introduced at one level have consequences on the entire system. Multi-agent systems often operate in one of two ways: as simulations of crowd or swarm behavior, or as two-dimensional plan-driven assignments that replicate conventional urban planning. A greater potential lies in the implementation of networked agent systems where multiple levels of agents operating on multiple scales, static or mobile, may address the differential conditions and relationships of an urban ecology.

Rabee Reffat describes intelligent agents as “agents that possess the following properties: autonomy, reactivity and proactiveness whereby they do not simply act in response to their environment, they are able to exhibit goal-directed behavior by taking the initiative.” (Reffat, 2006) Our six-week research in object-oriented programming focuses on a three-dimensional expansion of Conway’s Game of Life [1], a self-propagating program that produces complexity from a set of simple rules and begins to address some of the possibilities of networked agent systems. Built in Processing, the city’s evolution is controlled at three scales: the scale of the urban community, the scale of the buildings, and the scale of individual units. Each voxel, a three-dimensional equivalent of a pixel, represents a unit within a building and responds dynamically to collective conditions of its 26 neighbors. The behavior and evolving states of these voxels then inform the subsequent generations of buildings which in turn affect the urban development. However, the chain of intelligence is not linear. Rather, changes at the larger scale of the urban fabric also influence the conditions for voxel evolution, setting in motion a self-generative environment with complex configurations that could never have been individually predetermined. Each subsequent generation of the city is a result of the previous generations as well as the rules implemented at the localized level. [FIGURE 1 & 2]

Figure 1
Voxel neighbor checking at building scale.

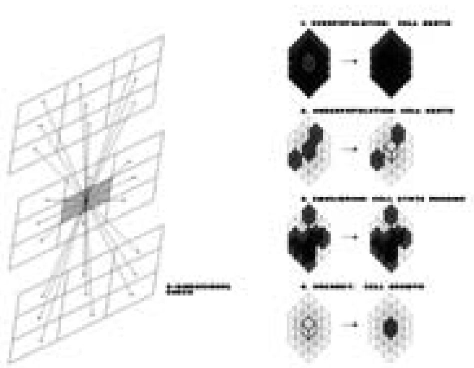
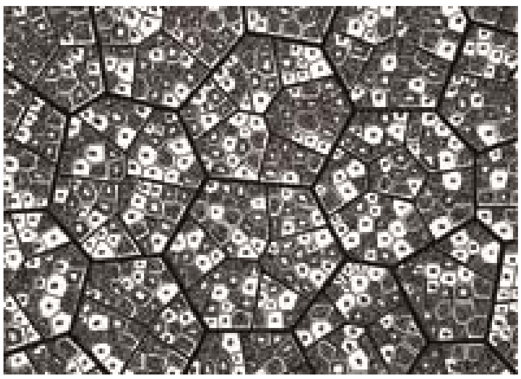


Figure 2
Neighbor checking at urban scale; voxels inform plots.



Design thinking necessarily shifts towards a more process-based and analytical methodology as the effort is no longer to understand the static configuration of a masterplan but to tease out the behaviors of a design over time. While the formal input and decision-making of the designer remains important, they are now backed by performance results tested at multiple scales. This emphasizes a non-linear design process that is itself organic, iterative and research based, integrating performance with form.

Collaborative Environment

The complexity of urban design means that different players with different goals and constraints are often working together. It is therefore important that there is a common platform that can be shared both as a means of communication but also as a means of collaboration. While there are quite a few BIM programs that are used for architectural projects, we are not aware of anything similar in urban design. An interface that allows for the parametric testing of design intentions means that several parties can work parallel and also synthesize the results towards a common goal. Changes implemented into the design by one party can be inherited by the next, creating a fluid back-and-forth collaboration with real-time results. Networked agent systems will allow designers, consultants and specialists to inform the design at various levels and witness the effects of the decisions over simulated time. Manuel de Landa even suggests the possibility of integrating authority structures into the agent system to fully simulate a planning process. (De Landa, 2009)

We do believe, however, that while a parametric program provides a much needed platform for goal-oriented research and collaboration, it is by no means an objective methodology. Each user will still have to provide the questions and parameters for testing as well as the criteria for evaluating results. In our test case, the data input through the interface produce variable results, however those results are meaningless without a context or a means of evaluation. The design team working together will still have to negotiate the project goals and the desired outcome, only now with a greater understanding and foresight of the possible scenarios.

Projected Potentials of Intelligent Agents

The recent return to Christopher Alexander's *A Pattern Language* paralleled the rise of parametric urbanism and the growing ecological concerns of our built environment, in large part because the book preaches a scalar and rule-based approach to design that is systematic yet adaptable to project specificities. One size does not fit all. And in fact, certain conditions and nuances at one scale could be counterproductive at another. (Alexander, 1977) However, most of the parametric simulations of urban environments are not yet able to implement agents intelligent enough to make informed decisions at multiple levels. To do that, they will have to be capable of synthesizing information, making evaluations, negotiating intentions based on dynamic relationships with other agents at different scales. De Landa calls this the "Belief-Desire-Intention" agents who do not simply follow rules or have limited tasks that they repeat but rather are capable of projecting intentions onto other agents thus creating a truly interactive agent system. (De Landa, 2009)

Despite the relative autonomy of the agents, and their potential for discreet decision-making, it should be clear that computation does not absolve the designer from making decisions. If anything, the responsibility is greater. The parameters of the script, the formal language, the chosen results all still rest in the hands of the designer who sets these variables in motion. At the same time, the speed of the tool and the versatility of the simulations allow an even greater set of choices. Within this expanded menu, designers must be trained to greater acuity to ask the right questions and discern the right solutions, keeping the big picture in mind while tinkering with localized decisions. With all the possibilities of programming, the dilemma is not where to start but where the decisions end.

Stephen Marshall argues that modern planned cities, as opposed to the organic development of historical cities, often present hostile environments because of their lack of complexity.(Marshall, 2008) Computation is not a shortcut for design or a recipe for automatic cities. Rather, it is a tool, and even a philosophy, that opens a new paradigm for urban thinking. The focus in planning is shifting from the grand visionary Masterplan as a static image to the design of dynamic relationships between the constituent parts of a city, resulting in a more complex urban environment and one that can potentially absorb changing conditions and desires. With the dynamic simulation and analysis tools of networked agent systems, urban design can be more effectively practiced as a time-based process, and one that addresses multiple scales of urbanism.

References

[1] A website by Paul Callahan documents the Game of Life as well as the many versions and experiments that have ensued since the mathematician, John Conway, first introduced the game in 1970. http://www.radicaleye.com/lifepage/

[2] www.caad.arch.ethz.ch

[3] http://www.casa.ucl.ac.uk/

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