TOWARD TEMPORAL AND PUNCTUAL URBAN REDEVELOPMENT IN DYNAMIC, INFORMAL CONTEXTS

An Adaptive Masterplan Driven by Architectural Interventions Using Multiagent Modeling

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Abstract. This paper presents design research speculating on new planning approaches for informal urban sites that enables coordinated planning to operate within the realm of spontaneous, bottom-up redevelopment. In opposition to the tabula rasa Modernist development, this project reacts to the dynamic metabolism of the village and engages with the rapid turnover of the built environment of the village as a mechanism through which to implement incremental redevelopment. A radical re-orientation of the object of masterplanning, this replaces the singular image or document as the guiding authority with a collection of opportunistic adaptations, temporal sequences, and localized procedures. Enabling this approach is a computational approach that analyzes the morphology of the public space network to identify opportunities to address issues in the composition of the village. A multiagent system driven by weighted random walks through the circulation network conducts local analyses of the urban fabric while changes are made and proposes potential modifications to discrete areas. The model simulates the potential for such a planning tool to be used over a long time span and updated with empirically gathered data, having the benefit of flexibility and resilience in the face of the changing and unregulated conditions in the context of informal urbanism.

Keywords. Generative design; responsive masterplanning; informal urbanism; network analysis; agent-based modeling.
1. Introduction

The village-in-the-city (城中村: ‘chengzhongcun,’ also sometimes called ‘urban village.’) phenomenon in Chinese cities—the result of rigid restrictions on migrant mobility and lack of effective urban planning restrictions in what are technically considered as rural lands—has been well documented (Chung 2015; Mullan et al. 2011; Wang et al. 2009). However, the majority of research focuses on those villages-in-the-city that are most embedded in the urban fabric (Zacharias et al. 2013). The villages of Haizhu island in Guangzhou are unique in that they are still surrounded by the remnants of agricultural land, the Wannu Orchard and Yingzhou Ecological Park, despite occupying a geographically central position within Guangzhou. This fact sets them apart somewhat from the pressures of the megalopolis and renders them more autonomous and self-contained units, which makes them well suited for limited studies like this one.

The test case is sited in Xiahzhoucun, one of the larger villages in Haizhu. Typical of many villages-in-the-city, there is a high degree of unregulated construction (and reconstruction following demolition) throughout the village to replace decaying structures or to increase housing capacity. This fact makes the strategy of punctual interventions appealing in contrast to a comprehensive masterplan (Kerez 2016). These construction processes are the sociomaterial interactions at the heart of the urban metabolism and influenced the decision to work with an insistently dynamic, process-based approach in the project.

Unlike many villages-in-the-city, the population growth of Xiaozhoucun is not dominantly driven by migrant workers, but by students who attend the nearby University Town and artists associated with the Guangzhou Academy of Fine Arts drawn to the quietness and tranquility of the village (Qian et al. 2013; Andersson 2012; Qian et al. 2012). Much of the attractive urban quality of Xiaozhoucun derives from the experience of walking through the warren-like alleys of the village and the small pockets of open space, especially along the river. Thus, the project focuses on the network of public space as the village’s characteristic feature and primary object and agent of change.

1.1. URBAN NETWORK MORPHOLOGY

Historically, the dominant practices of urban morphology have been concerned with defining morphological regions through identification of historical forms of development (that is, with similar relationships between of ground plan, built fabric, and land use) and identification of typological processes (Sima & Zhang 2009; Whitehand 2001; Oliveira et al. 2015). A trend toward more procedural definitions is apparent in recent methods that merge the analytical power of computational processing with the precision of GIS software (Jiang 2000). This project builds on work in Urban Network Analysis, that represents urban morphology as a network of intersection nodes connected by links that correspond to street sections, a method sometimes referred to as the primal graph (Sevtsuk & Mekonnen 2012; Porta 2006).

One criticism of primal graphs is that a single section of the street may actually have many different qualities, resulting in an analysis with a lower resolution
and one that varies unevenly depending on the network morphology. Sevsuk and Mekonnen address this concern by including building entrances into the network as additional branches from the street segments, enabling the use of floor height, use, or occupant load to add weighted values to the urban analysis. This works quite well in contexts with a high proportion of standalone buildings, however in Xiaozhoucun the built environment is a near-continuous fabric of buildings. In this project we address the concern by subdividing network segments at locations where the street width changes significantly and by adding additional segments at the location of party walls that separate adjoining buildings. This gives a much finer resolution to the network and renders the building volumes a more integral part of the network itself.

1.2. MULTIAGENT SWARMS

In order to address the informal context of the village without imposing a deterministic plan, the project uses a swarm of agents to conduct localized, rather than total, actions. These agents both read the urban network morphology analytically and encapsulate behaviors for exploration and redevelopment that capture the intelligence of the village metabolism (Leach 2009). Swarm intelligence is often seen as a useful way to replicate or work within informal urban settlements because it reproduces an environment where behavior logics engage and adapt to one another in the absence of a central control or guiding masterplan (PanahiKazemi & Rossi 2013). Furthermore, an agent-based system is well-suited to dynamic modeling and the responsiveness it requires (Kuo & Zusinger 2010). Within network analysis, multiagent systems have also been shown to be effective tools for identifying network features such as clustering patterns (Harel & Koren 2001; Alamgir & von Luxburg 2010).

2. Methods

2.1. NETWORK DEFINITION

Within the model, the existing village was redrawn as a network from a standard cadastral plan. This network is formatted as a customized half-edge mesh such that mesh edges represent segments of circulatory space or party walls between adjacent buildings. Unlike many urban network analyses, the model also engages with the mesh faces, which represent individual parcels (built or open), such that the half-edge datastructure is not merely a technical expediency, but a direct analogue of the representational schema. Mesh faces and edges are defined as object classes with a number of properties for metadata such as built height or clear width. Even the relatively compact village of Xiaozhoucun is composed of over 850 parcels and 3800 edge segments, so the model also includes methods for automatically importing and assigning the metadata values from a standard figure-ground image file making initial conditions easy to update. Figure 1 shows this base image file and the resultant mesh rendered with either edges or faces visualized.
2.2. AGENT DEFINITION

Preliminary analysis indicated that the village's circulation network, though extensive, was characterized by discontinuities and long, dead-end alleyways. The agent walks have two purposes: the first is to stochastically record bottlenecks and clusters in the circulation network by recording the aggregate traffic volume over time (these values are stored as properties of the mesh edge class). The second is to conduct comparative analyses of the urban network localized at the agent's position to indicate potential for minor changes that would open up significant new connections.

The half-edge mesh provides the ground for the agent swarm. Agents occupy nodes and are able to move along any incident half-edge with a non-zero width. The direction of travel is selected randomly from a list of the available directions and can be weighted according to the path widths (direct backtracking is precluded except in the case of a dead-end). The random walks were tested with three parameters for direction selection (figure 2, columns): an unweighted list in which each possible direction was counted once; a linear weighting in which possible directions were counted according to their width in meters, wider paths thus having a greater chance of being selected; and an exponential weighting in which possible directions were counted according to one half of the square of their widths, wider paths having a much greater chance of being selected. The exponential weighting resulted in many sections of the network being ignored while the unweighted option had the most even coverage. Ultimately it was decided that the bias toward larger thoroughfares resulting from a linear weighting was the best option for the model because these paths were also high traffic areas in the real world and because it would lessen the impact on the urban character created by the narrow alleyways.

Another parameter that was introduced was to give the agents a lifespan, after a certain number of steps, the agent would be removed from the simulation and a new agent spawned at a randomly selected public space. This was done to prevent agents from becoming stuck permanently in a loop or dead-end and unbalancing the results. Testing with different age parameters (figure 2, rows) showed that a high threshold of 90 steps did not do much to combat the problem of repetitive movements, while a low threshold of 10 steps often prevented the random walks from spreading far enough from their initial locations. A threshold of 50 steps was chosen for use in the model.
2.3. LOCAL NETWORK ANALYSIS

In order to assess the potential of a location for alteration, each agent is programmed to calculate the local graph of all navigable edges that could be reached from its current location within a limiting depth, in this case 75m (this limit value was selected after early tests indicated that the selected edge always fell within this
The travel distances required are compared to the distances for the same points that would be possible if all edges of the mesh were used, including those that are currently not traversable. The point from the first graph that had the greatest reduction of distance is selected and the shortest path to it highlighted. Any segments along that path that are not traversable are identified as potential shortcuts and an aggregate value counting the number of times an edge is designated as a potential shortcut is saved as a property of that edge (figure 3).

Figure 3. Left: A depth map from an agent location over the circulation network, localized to 75m; Right: the same depth map including also non-traversable edges as potential connections with the most impactful shortcut highlighted in blue.

2.4. TEMPORAL REDEVELOPMENT

As the simulation runs, the mesh faces periodically assess the total traffic and shortcut values over all their perimeter edges. If the sum exceeds their own persistence value (a value assigned at the beginning of the model that declines as the building ages) they are considered for replacement. At most, one face per interval is selected, if that face has an existing building on it, it is demolished and rebuilt at a higher density. The reconstruction is defined on the model of the village’s existing pattern of building (new construction is typically concrete frame with brick infill) and of recycling material from adjacent demolition (pending more in depth site surveying, we assume that existing structures are masonry cavity wall construction typical of older, low-rise building in the village). The material available defines the maximum height of the new construction in the model. The primary feature of the proposed new construction is the definition of open pathways at any edges that had accumulated high shortcut values as well as greater setbacks on any edges that had recorded excessive traffic volumes compared to their previous width. After a parcel is selected for reconstruction the agent swarm and edge values reset and new agents are spawned from various public spaces in the village. Subsequently all agent walks and analyses use the new width values in their operation. Figures 4 and 5 show screenshots of the model in operation.
3. Results

After running the simulation for 5000 cycles, the model had widened or opened 653 edges and reconfigured 379 parcels (32.3% by count or 29.5% by area)-62 of them as new open plazas (figure 6). From the built floor area, 70,000m² of the original 190,000m² were replaced and extended with the result of nearly doubling the FAR from 1.27 to 2.48, reaching a total built area of 370,000 m². Interestingly, the sites of redevelopment are distributed widely across the site as truly punctual interventions and not primarily within common zones. Interventions increased in frequency as the simulation progressed due to the advanced aging of the original building stock.

Figure 4. The path of the agents random walk is recorded as a traffic value by the edges. Currently calculated shortcuts are shown by the dashed line. The combination of these values is visualized as the color of the edges.

Figure 5. A volumetric visualization of the simulation with a live tally of total built floor area. Yellow volumes are new constructions. In-process demolition (red arrows) and reconstruction (yellow arrow) can be seen in this frame.
With regard to the original goal of addressing inefficiencies in the circulation network, the eccentricity of the network was calculated before and after the simulation was run: from each node in the half-edge mesh the geodesic distance to every edge was calculated and the highest value stored. The median eccentricity of the initial circulation network was 565.45m and the diameter (the single longest
direct distance between two points) of the network was 775.73m. These values decreased to 508.65m and 702.13m, respectively (figure 7). This change was effected by opening up around 4.14km of new alleyways, a sizable number in comparison to the pre-existing network length of 16.7km, but quite small when one realizes the average addition was only 6.93m. An additional 417m of pathways were widened slightly by 1 meter increments.

4. Conclusions and Further Work

The model developed here demonstrates the capacity to guide development in an informal context without resorting to a totalizing plan—even with only a few simple parameters. Despite the lack of centralized coordination, the selection of parcels is consistent and overall urban composition remains coherent and functioning throughout. The decrease in the median eccentricity and diameter values shows how strategically positioned modifications can offset relinquishing control of the end result. While it might be possible to optimize the impact of interventions by working back through the alterations and removing redundant changes, we feel that would go against the primary goal of a planning tool that is meant to be reactive and resilient to external changes. A few concerns about the model behaviors include the homogeneity of the potential network—new alleys and new bridges are treated the same, though a bridge would be significantly more expensive—and whether the acceleration of intervention frequency, though reflective of real obsolescence concerns, allows the analyses to sufficiently inform the selection process.

As a design tool, there are a few drawbacks. Creating the initial network may be a negligible step in well-documented areas (the same format is used by openstreetmap.org), but in informal contexts, this information is less likely to exist. Tracing the urban network is time consuming and prone to introducing errors. The method used for data input from image files was, however, quite successful in reducing the time needed to populate the model with fuller data. Better methods for controlling the flow of time in the model, especially starting and stopping the simulation, would improve the performance and memory loads as well as allow adjustments to changing onsite conditions.

The simulation would benefit greatly from increased empirical data regarding the existing building stock, especially the building construction techniques, age, and extent conditions. Currently, the values used for these are too homogeneous to indicate how the model would perform in actual use. Similarly, more data about the social and programmatic use of space would be useful to compare against the projected changes and to fine tune the agent behaviors.

Within the computational model there are two aspects that warrant further work. The first is to address the static, discrete nature of the mesh faces. Given the small size of the average parcel, increases in overall density will face a limit based on the necessary vertical circulation. A natural solution would be to allow adjacent, small parcels to share a staircase or elevator core, enabling taller constructions to also be considered. This would require more communication between a mesh face and its neighboring faces, but once implemented could be used for a number of purposes, such as air rights negotiation and privacy from vis-à-vis relationships.
The second focus is to study more closely how the multiagent random walks compare to other methods for defining clustering, such as spectral graph analysis, and to develop a more standardized set of metrics to compare agents with different parameters so that they can be benchmarked against these static methods.

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