Meta-Zoning Logistics

Dave Lee

1Clemson University (CU)

Abstract

To the architect, city zoning ordinances that pertain to site setbacks and building envelope profiles are often viewed as restrictive and introduced late in the design process. Conversely, to the urban planner, building design that is more individual, varied, and/or formally sculptural can be viewed as having a negative impact on the urban fabric. Is there a way to create a healthy dialogue between these seemingly polarizing disciplines with a common language?

This research proposes a parametric model for schematic building design that integrates any city’s zoning ordinances and gives visual feedback to the designer regarding the setback, profile, and Floor to Area Ratio of their solution. Furthermore, through the integration of real-time geospatial input, the parametric model adds specificity accounting for site coordinates, neighboring plots of land, and zoning designation in the solution. Two parallel streams were simultaneously investigated, one that examined the localized condition of a single parcel and one that more globally considered the urban condition.
1 Introduction

The Tenement House Act of 1903 (OASIS, 2010) and the Zoning Resolution of 1916 (NYC DCP, 2010) were written in response to unsafe and unhealthy building conditions that had emerged in New York City as it underwent rapid growth. These documents aimed to remedy widespread problems with construction practices - primarily concerning structure, lighting, and accessibility – but were also innovative in their designation of districts within municipalities that would each have specific building regulations. With these publications, a modern zoning code was first established in the United States. While building codes have evolved some over the past century, the basic structure and much of the terminology used in the original document remain consistent and relevant today.

Of all limiting factors in the design of a building, site geometry and zoning designation are two early indicators of potential design outcomes. Ironically, these conditions – zoning ordinances, in particular – tend to be introduced late in the design process or as restrictive to the architect. One reason for such disjuncture may be the lack of visualization tools designed specifically for pre-design and schematic design of buildings. Even with associative modeling becoming increasingly popular as an integrated design tool, such software largely overlooks the impact of zoning and site on building design.

Zoning information is almost exclusively found in a text-based form and when found graphically, is rarely presented as a volumetric representation. When read from the perspective of computation, zoning codes are essentially a set of parameters written to describe a range of possible conditions to design and build within. Building code is necessarily written in an explicit manner and its clarity of purpose makes it a perfect candidate for parametric modeling. With parametric modeling tools, translating the text of building code is a relatively simple procedure, making it possible to visualize design variations in a dynamic manner with respect to building codes.

The first aim of this exploration was simply to recreate a single zoning code using parametric tools in order to better understand how to best visualize them in a functional manner. This was done using all parameters defined in the original New York City zoning documents that relate to site type and building envelope (Figure 1).

Two limitations of this method are that only generic site conditions are explored and only a single city’s zoning code is applied. Whereas the aforementioned parametric model creates a finite list of solutions from which the architect must select, this research is meant to offer a flexible way of designing within the framework of zoning regulations and offer possibilities not yet realized within it. In order to do this, specific site conditions and zoning codes must be integrated into the model. The next approach of this research was to develop a method for integrating a Geographical Information Systems (GIS) database of site data into a parametric model and applying local zoning ordinances to the model.
2 Parsing the Data

GIS have proven to be an invaluable resource for gaining access to an extensive database of relational mapping information, making them ideal for collecting site data. Their widespread influence can be largely attributed to efforts in the standardization of geospatial data structuring. Indeed, the dissemination of this information through commercial mapping software has offered architects and planners a powerful and dynamic analytical toolset for associative data visualization.

There remains a potential, however, for GIS data to be cross-referenced with other important sets of information that are integral to the design process. One such area concerns local zoning ordinances and their impact on site and schematic design. Zoning ordinance data, in association with readily available GIS information such as land parcels, roads, and other physical information can provide a framework to examine building location and envelope. GIS contain very large datasets, but they are well structured (ESRI, 1998). Because of this it is relatively simple to cull particular sets of information from the database.

This workflow is implemented using a plug-in for Rhinoceros, Grasshopper, that incorporates a graphical algorithm display. An important goal of this project was to be able to read data from remote files and cleanly write to various components within the Grasshopper interface without having to import/export with other software packages. Doing so streamlines the system and makes the design tool a much more accessible and practical option for architects in what is typically a time sensitive period in a design project.

Building on the work of Nicholas Monchaux et al (2010), who have created a method for importing and organizing Rhinoceros files in Grasshopper, GIS data is brought into a Grasshopper component scripted the using VB.net programming language. VB.net was used because it is supported by current builds of Rhinoceros and Grasshopper. The component outputs geographical information read directly from GIS Shapefiles through the Grasshopper interface as parametric data, meaning there is no need to first import into Rhinoceros (figures 2,3). Because of the volume of data contained in GIS, only the information necessary for the algorithm is imported.

Figure 2. Workflow of data reading, culling and conversion.

Figure 3. ArcGIS data imported through Grasshopper interface.

3 Site Specific Zoning

A major hurdle to overcome in the integration of zoning data with geospatial data is the nature and complexity of the information being collected. There are two significant factors that contribute to this. First, each municipality has its own political and cultural complexion, and therefore its own guidelines for how it chooses to manage and develop land. Second, geography and
climate can vary widely. Data contained in zoning ordinances does have common categories, with many shared definitions and labeling procedures, but there is not a universal standard. To make it possible to define a set of parametric conditions that can adapt to any code without having to customize for every city, some standardization must occur.

4 Visualizing Zoning Data for Pre-Design

The parametric model that was developed can account for neighboring plots on three sides as well as street width and specific building setback designations as per zoning district.

4.1 Setbacks

Ground level setbacks were given three designations: road frontage boundary, site connection lines (site/site boundaries), and rear yard. All sites have at least one of these conditions, but not all sites have all conditions. A second variable determines whether neighboring sites have existing buildings and their current setback values. In the algorithm, setbacks are treated as a minimum offset value.

4.2 Vertical Setbacks

The notion of establishing vertical datum to respect a human scale at the lower portion of buildings as construction technology pushed their heights to new extremes was first introduced by Dankmar Adler and Louis Sullivan (Twombly, 1998). It was among several planning concepts introduced in their work and writings of the late 19th century that contributed to New York City zoning code.

A simple formula, establishing a datum calls for building exceeding a given district height to be recessed a minimum number of feet at any point above said district height. However, buildings constructed under differing zoning conditions, be they along a seam between districts or a product of changing rules over time, often have different setback heights. Variations that were explored include averaging corner height between neighboring buildings, connecting a straight line between neighboring buildings, and a b-spline connection between neighboring buildings (figure 6). These experiments point at broader potential research as to how other civic factors such as street width and landscaping might contribute to the establishing of a building datum.

Therefore, this research proposes an optimization of zoning code such that similar zoning conditions are categorized with the same labeling procedure (figure 4).

With this system in place, a parametric model can readily organize and distribute sets of information collected from various municipalities (fig 5 see chart – data collected). This data is input into several algorithms describing the various zoning conditions, with adjustable parameters for control and optimization, which produce a visualization of buildable volume possibilities (figure 5).
4.3 Sky Exposure Plane

The vertical sky plane, which accounts for adequate ground level lighting conditions, is input here. By default, the sky plane is calculated perpendicular to the curve at the midpoint of each road frontage boundary line. It is defined as a ratio of vertical distance to horizontal distance, beginning at a designated height above street level. Variations that were explored include curved site boundaries, multi-edged site boundaries, and composite profiles.

4.4 F.A.R. + Maximum Building Height

These characteristics are calculated together for the obvious reason that an F.A.R. value lower than the maximum allowed on a site can easily be achieved while keeping a very large structure. By keeping a height limit in the calculation, the visualization will automatically cap the building height at the last complete floor level. The algorithm will also allow for real-time editing of floor plate dimensions to optimize a design. The algorithm allows one to adjust floor-to-floor height to display maximum F.A.R. build-out and also allows customizable floor plate depth (figure 7). Incentive programs such as inclusionary housing that offer an increase in allowable F.A.R. in return for meeting certain criteria are generalized in the formula by including an F.A.R. override option. It would otherwise be impossible to predict or account for all permutations.

Figure 6. Datum variations. Straight line and b-spline corner point connection types.

Figure 7. Floor Area Ratio variations testing geometry variations.
4.41 Population Density

Zoning designations as a result of urban planning strategies can have a dramatic impact on the quality of life and economics of a city. One factor that is heavily influenced by the maximum height and allowable F.A.R. of a zoning district is the resulting population density of a neighborhood. In general, the higher the F.A.R. value, the higher the potential for increased density, particularly in the case of residential designation. However, the infrastructure necessary for some high-density outcomes is not possible with a formula that does not consider density and land-use together.

As an alternative planning scheme, this experiment uses potential population density as a primary control for the build-out of cities. The algorithm accounts for density, maximum height, and a weighted percentage of building/land use (figure 8).

4.42 Topography

Topography is not typically a factor that is considered in general zoning calculations, however its geometric relationship to the buildable area and possible impact on the building height, as particular concerns, make this data interesting to consider in the context of this project.

The buildable height is typically a fixed number and is calculated from the centroid of the site. When site topography is considered over multiple parcels of land, the resulting elevation profile of a series of buildings at maximum build-out will not be level, but stepped as a result of the averaging of site elevation conditions. In cases where cities have extreme topographical changes the elevation profile becomes more pronounced.

This experiment questions the absolute vertical offset typically specified as a maximum built height on a site (localized) by posing an alternative flexible (global) maximum height. The flexible height is set at a specified distance above sea level, creating a unified datum for initial, human scaled, setbacks as well as maximum building height (figure 9).

Figure 8. Population density control of maximum building height.

Figure 9. Topographic control of maximum building height.
5 Geographic + Infrastructural Anomalies

Elements such as bodies of water, landmarks, mass transit, and institutional and mass assembly structures often require special zoning considerations and their zoning considerations are often more politically driven than shaped by existing code. For these reasons such elements have not been included in this study.

6 Future Explorations

6.1 Importing Building Volumes

The initial motivation of this project was to create a self-contained design tool that would allow for exploration of possible building location, orientation, and profile solutions. In recognition that a tool capable of analyzing building envelopes that have been modeled previously would be also be desirable, an option to import geometry was tested. Because the algorithm is only concerned with building locations, dimensions, profile, and volume, it was not necessary to incorporate models of a fine resolution. Imported models that performed best were those with a simple bounding volume. An item that will require further study is the parametric control of building envelope with imported models.

6.2 Sun Path Optimization

As a variation of the vertical sky plane requirement that is a component of some zoning designations as a right-to-light solution, a more complex calculation of actual sunlight-to-shade ratio at ground level can be calculated to optimize a building profile. There are several examples of research exploring building profile with regard to building issues such as heat gain, however this research would aim to more precisely control building profile as a function of desired lighting conditions in the open environment.

7 Conclusion

When site and zoning information are introduced graphically, through a dynamic toolset, architects are provided more opportunity to explore design variations with building placement, organization, and envelope. The result is a parametric model that incorporates both site and zoning information as input and returns dynamic representation of possible solutions. Additionally, with this parametric model defined, it is possible to explore design variations that look beyond the given rules outlined in a zoning ordinance to ones that aim to experiment with new possibilities. Although zoning ordinances vary from city to city, both zoning and GIS terminology are consistent enough for any location to be used with this parametric model.

An item not otherwise discussed in the scope of this paper, and subject of further research, is the opportunity for a parametric model to be exported and further investigated on other platforms that support associative modeling and real-time visualization.

References


The Tenement House Act (1903). NY, Tenement House Department.