



ACADIA 2011 Regional Parametricism (SPC)

There are five essential folding techniques including the reverse fold, mountain, waterbowl, and diagonal (Figure 4). Each possesses unique formal qualities and a unique range of motion. (Figure 5 represents a matrix of folding techniques and possible applications.)

The flexibility of the folding technique allows for an almost infinite number of variations to be created by manipulating the crease pattern (Domene, 2007).

3 Digital Origami

The tool that was developed uses the surface crease pattern to define the possible movement of the digital model. If the surface's form is manipulated, the base crease pattern will automatically adjust to the deformation, yielding a new pattern with the same surface topology. Several folding (kinetic) analog models were created leading to the development of the algorithm, each using variations of origami folds.

In constructing a catalog of folds, constraints and an embedded range of solutions the Grasshopper graphical algorithm editor was used in concert with Rhinoceros. The algorithm works by defining a sequence of operations linked to the various folding properties of the five folding types investigated. There is a root folding sequence that may be repeated as many times as desired, eventually a kinetic pattern (Figure 5). Each subsequent surface is defined off the original geometry through a series of constraints: move, mirror, and rotate. The limitation of the digital folding of the model is decidedly more complex to define into the kinetic movement of repeated folds must have their own axis and center of gravity as well as be linked to those of the entire surface.

Figure 4. Variations of folding types.



Analog Parametricism

An analysis of the movement of each face in the system led to an discovery that it is possible to maintain the kinetic movement of the system by rotating along a single edge of each face. This allowed us to trace uninterrupted paths of movement from end to end, through the surface of the system. Mechanically, this was executed by connecting certain axes with a universal joint (Figure 6). This joint allows torque to transfer from one structural member to another through torque conversion. The torque then provides the energy to fold the model. Origami possesses similar traits to helices and fibrous. The great allow for creating structure with a thin material.

Another important factor and one explored in greater detail with this project, is the potential for the kinetic movement of a paper folding sequence to be adapted to human scale. While some of the folding types reveal along only one axis, the Waterbowl fold moves simultaneously in four axes. A mechanical folding of the Waterbowl was explored that acts along the surface of the material so as not to interrupt the topology of the fold.

4.3 Return to Analog

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4.4 Scalability: Joints + Connections

The digital simulation provides precise data on the size of the model when it is expanded and when it is collapsed. This is the first time in being able to use this model on a large scale. One consideration that must be accounted for when scaling this work for architectural production is the thickness of material. Tensar's Tuff-Form 2000 has presented research that explores this problem with consideration of the fold, to account for the theoretical collapse of two faces upon one another.

Figure 5. Waterbowl folding morphology.

Figure 6. Using a universal joint as a torque converter to allow mechanical movement of a system.

Digital Origami: Modeling planar folding structures

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This paper presents a surface manipulation tool that can transform any arrangement of folding planar surfaces without the need to custom program for each instance. Origami offers a finite set of paper-folding techniques that can be catalogued and tested with parametric modeling software. For this work, Rhinoceros and Grasshopper have been chosen as a software platform to generate a parametric folding tool focusing on single surface folding, particularly where surfaces can transform from one configuration to another while retaining their planarity.

Folding surfaces, particularly complex crease configurations can be modeled digitally and tested in variation using this algorithm. This makes it possible to design and test any folding pattern configuration by simply creating a flat tessellation pattern. Because this algorithm is inherently without scale, it has the potential to be implemented on a wide range of applications including retractable walls, roof structures, temporary structures, tents, furniture, and robotics.

Figure 1. Origami Classifications and architectural application.

Figure 2. The flexibility of the number of creases meeting at a point is 180 degrees.

Digital Origami: Modeling planar folding structures

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Introduction

To fold something is to lay one part back onto itself. In some folding is either subtractive or additive, but instead is self-referential. The most intriguing moment of the fold is the cross from one dimension into another. For example a piece of paper is flat and takes the properties of a three-dimensional shape, though the paper is still a two-dimensional surface. With a combination of single folds and one piece of paper may address some fundamental aspects of architecture by acting as both structure and skin simultaneously (Figure 1).

As an analog parametric technique, paper folding has its limitations. Working with folding planar surfaces in digital modeling applications is equally problematic because one is normally only able to manipulate components locally, one at a time. When modeling transformable surfaces it is helpful to be able to simulate surface movement, but there is currently no way to globally affect rigorous surface transformations without custom programming for each individual case. This research proposes a parametric surface manipulation tool using that can transform any arrangement of folding planar surfaces without the need to custom program for each instance.

2 Paper-folding Procedures

Origami, the Japanese art of folding paper into intricate designs and objects, provides precedence for mathematics, science, art, and architecture. Certain geometrical problems, such as inscribing an angle and doubling a cube are impossible to solve with a compass and straight edge yet possible with paper folding. Origami works through its own geometrical rules based on the relationship of lines, points, and planes. The mathematician Huzita Huzita formulated six axioms that map points and lines to help construct and explain folding schemes. These axioms are based on the fact that folding is an accurate and precise quantifiable operation. The

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Meta-Zoning Logistics

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Abstract

To the architect, city zoning ordinances that pertain to site setbacks and building envelope profiles are often viewed as restrictive and embedded into the design process. Conversely, to the urban planner, building design that is more individual, varied, and/or forward-looking 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 ordinance and gives visual feedback to the designer regarding the setback, profile, and floor to area ratio of their building. Furthermore, through the integration of real-time geospatial input, the parametric model adds specificity accounting for site coordinates, neighboring plots of land, and zoning designations to single parcel analysis. These scenarios are being simultaneously investigated, one that examined the localized conditions of a single parcel and one that more globally considered the urban condition.

Meta-Zoning Logistics

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Introduction

The first aim of this exploration was simply to create 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 the site and building envelope (Figure 3).

Of all limiting factors in the design of a building, site geometry and zoning designation are two early indicators of potential design outcomes. Invariably, these conditions - zoning ordinances, in particular - tend to be introduced late in the design process or as a restriction to the architect. One reason for such design rigidity 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 in a volumetric representation. When viewed 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 necessary written in an explicit manner and its clarity of parameters is a particular challenge 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.

Figure 1. Aggregation of building code parameters, building to, processing of outcome, Maximum building height, Rear yard provision, Side/lot front provision.

Figure 2. Two iterations of this method are that only one zoning condition are explored and only a single city's zoning code is applied. Whereas the aforementioned parametric model creates a finite set of solutions from which the architect must select, this research is meant to describe a flexible way of designing within the framework of zoning regulations and other 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 System (GIS) database of site data into a parametric model and applying local zoning ordinances to the model.

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1 Introduction

The Treatment House Act of 1903 (DOCS, 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 a result of rapid growth. These documents aimed to remedy widespread problems with construction practices - primarily overcrowding, 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.

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2 Parsing the Data

GIS has proven to be an invaluable resource for gaining access to an extensive database of relational mapping information, making them ideal for collecting site data. Because of the volume of data contained in GIS, only the information necessary for the algorithm is imported.

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 contains very large datasets, but they are well structured (SUN, 1998). Because of this it is relatively simple to cut particular sets of information from the database.

This workflow is implemented using a plugin for Rhinoceros, Grasshopper, that incorporates a graphical algorithm editor. An important goal of this project was to be able to read data from remote files and apply them 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, which is typically a time sensitive period in a design project.

Building on the work of Nicholas Mouchawar et al (2010), who have created a method for importing and organizing Rhinoceros files in Grasshopper, GIS data is brought to a Grasshopper component scripted the using .Whatnet programming language. Whatnet was used because it is supported by current builds of Rhinoceros and Grasshopper. The component utilizes geospatial information read directly from GIS Shapefiles through the

Grasshopper interface as parametric data, meaning there is no need to first import into Rhinoceros (Figure 2.3). Because of the volume of data contained in GIS, only the information necessary for the algorithm is imported.

Figure 1. Workflow of data reading, cutting, and conversion.

Figure 2. GIS data imported through Grasshopper interface.

Figure 3. GIS 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 naming 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.

This system in place, a parametric model can readily organize and distribute sets of information collected from various municipalities (Fig. 3) into a data collection. 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).

Figure 4. GIS data imported through Grasshopper interface.

Figure 5. GIS data imported through Grasshopper interface.

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 districts.

4.1 Setbacks

Ground level setbacks were given three designations: road footage boundary, site connection lines (sideline 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 Calverley Adler and Louis Sullivan (Theorby, 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 call for building exceeding a given district height to be reduced a minimum number of feet at any point above said district height. However, building contextualized over differing zoning conditions, but they along a same between districts or a product of changing rates over time, often allows for a product of changing rates over time, often allows for a product of changing rates over time, often allows for a product of changing rates over time. Variations that were explored include averaging corner height between neighboring buildings, connecting a straight line between neighboring buildings, and a higher connection between neighboring buildings (Figure 6). These experiments point at broader potential research as to how other site factors such as street width and landscaping might contribute to the establishing of a building datum.

4.3 Sky Exposure Plane

The vertical 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 footage 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. In 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 mid-stair 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 spline corner point connection.

Figure 7. Floor Area Ratio variations testing geometry variations.

4.4.1 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 sites. The algorithm accounts for density, maximum height, and a weighted percentage of building/land use (Figure 8).

4.4.2 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 sites 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 (located) by posing an alternative flexible (global) maximum height. The flexible height is set at a specified distance above site 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 specific zoning considerations and their zoning considerations are often more idiosyncratically driven than shaped by zoning codes. 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 relative to the design tool a much more accessible and practical option for architects, which is typically a time sensitive period in a design project.

As a variation of the verticality plane requirement that is a component of some zoning designations as a right-to-light violation, 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 tool, 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.

As items 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.

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