PARAMETRIC THINKING IN URBAN DESIGN

A geometric approach

NICOLAI STEINØ
Aalborg University
Department of Architecture, Design and Media Technology
steino@create.aau.dk

Abstract. The paper states that most applications of parametric modelling to architecture and urban design fall into one of two strands of either form for form’s sake, or the negotiation of environmental concerns, while approaches which allow scenarios to be easily tested and modified without the application of complex and expensive technologies are mostly absent, although they seem appropriate in urban design. A survey of existing approaches confirms the statement, and an example of the application of basic knowledge of geometry and parametric thinking to urban design forms the argument of the paper. The pros and cons of this simple approach is discussed, and the paper concludes, that while it does not represent a suitable solution in all cases, it fills a gap among the existing approaches to parametric urban design.

1. Introduction

Parametric design is well established in engineering and is increasingly applied in architectural design. In urban design however, despite obvious potentials, is still in its relative infancy. While urban design academics have long speculated about parametric urban design, and some explorations have been made with regard to the application of parametric design software, an actual breakthrough does not appear to be imminent, even though the first dedicated commercial software packages are now emerging.

In a recent article, Tim Love (2009) divides the adoption of parametric design to architectural and urban design into two strands. At the one end of the spectrum, parametric design tools are used for “gee-whiz form-making”, while at the other, the same technology facilitates “a metric-based emphasis on social and/or ecological relevance” (ibid.). While contending that the two
opposites often appear alongside each other, he is critical of both. On the one hand, the form-making approach seems to mask a lack of genuine form-making competency through complex forms generated from data of inscrutable origin, while on the other, what seems to be a concern for the environment is too often a veil of chastity over designs which are merely explorations of form:

[I] it’s too often the case that the process of creating forms by inputting and manipulating data does not require that the designer develop a nuanced and comprehensive design strategy; and the process itself can produce a spurious and easy complexity that masks the absence of that more expansive approach. In some projects, for instance, specific cultural, social and physical contexts are deployed mainly as tactics for autonomous form making.

– ibid.

Notwithstanding the evident benefits of advanced parametric software, they require both investment, maintenance and skills on behalf of the user, which is not always available in small or more generalised settings, such as smaller consultancies, municipal planning offices, let alone among lay people. While urban design is very often a collaborative endeavour, where many different views and concerns must be negotiated among a fan of stakeholders, advanced technology and high skill requirements are likely to be a limiting factor rather than a liberating one. Therefore, it is desirable to achieve conditions where the power of a parametric approach can be implemented while still maintaining a low entry level, both economically, technologically and in terms of required skills.

So even though approaches that apply highly sophisticated software attract the most attention, a low-tech approach that requires more accessible tools and more modest skills deserve attention, particularly when it comes to the analysis and negotiation of urban space. In other words, approaches which allow scenarios to be easily tested and modified without the application of complex and expensive technologies and accompanying levels of skill are very appropriate in urban design. Furthermore, the collaborative potential of parametric design (Burry, 2003) seems important in this context. But as the following review reveals, such approaches are not abundant.

2. Some different approaches

At the high end of the scale, the CityEngine software programme (Procedural, 2010) is a procedural modelling tool based on shape grammars and targeted at modelling at the scale range of buildings to entire cities. Plans can either be generated parametrically or based on input data.
Buildings and streets are created parametrically, either via the software’s interface for controlling the different parameters or – for the advanced user – from scratch through scripting. A special feature allows for the intuitive control of parameters via image maps (ibid.). Priced in the area of USD 5,000 for a pro license and an additional annual fee of USD 2,000 for upgrades and support, the software is targeted at highly specialised, professional users. In addition to architecture and urban design, the software also addresses the game development, virtual worlds, and archaeology and heritage markets.

More specifically targeted at urban design and city planning, CityCAD is a parametric modelling tool for conceptual city design (Holistic City Software, 2010). While aiming at a higher level of abstraction, CityCAD offers less control of architectural detail and photorealism than CityEngine. Instead, it’s power lies in the capacity to relate spatial information to numerical information. Designs, in other words, can be evaluated against building and planning codes and regulations.

Also targeted at urban design, Modelur, a plug-in for SketchUp, is a simple massing tool for site design. Based on preset input data such as plot size, floor space index, building factor, and building parameters such as floor height and number of floors, the plug-in allows the user to convert 2D shapes into building entities which meet the presets. These can be copied and modified, and ‘survey’ data such as gross floor area, and the recommended number of parking lots can be returned for the entire site, as well as for individual buildings. Much more limited in scope than the two full software packages mentioned above, Modelur (still in beta at the time of writing) is free of charge.

Apart from these commercial products, different approaches to parametric urban design are also being developed by urban design practitioners and in the academic world. For some time now, the limitations of static masterplans has been the topic of many projects which aim at introducing dynamic plans based on parametric thinking. Rhetorical and conceptual in nature, the “Function-mixer” by the Dutch architectural office MVRDV represents an early example. The Function-mixer is a means to mix different uses in 3D-space by the generation of site plans and urban design schemes. The ideal mix is achieved by setting values for different programme parameters (Steinø & Veirum, 2006).

In his thesis work, Andreas Lykke-Olesen examined the design potential of viewing the city as consisting of interrelated and constantly changing systems of data. In order to be able to handle the data in a computer model, Lykke-Olesen’s focus was to ‘parameterise’ different kinds of data. In Robert Haff-Jensen’s competition entry for the Myllypuro Dynamic Masterplan, both form and use is defined parametrically, as a set of building typologies and different dwelling sizes respectively. By means of a dynamic web-
interface, different building typologies, as well as different combinations of dwelling sizes may be set for different parts of the dynamic masterplan (ibid.). And more recently, the German office N2M’s entry to the recent Life & Health City masterplan competition in Wuhu, China, aims at enabling the planning system to react to various impacts and changes, based on an analysis of issues which appear during the planning process (N2M, 2010).

While these examples are all applying parametric thinking to urban design, they do not rely on CAD applications for parametric design. While sharing the same concerns about static masterplans, Schnabel (2008) in his parametric urban design studio setup applies building information modelling in the form of Digital Project by Gehry Technologies to urban design. However, in this setup, focus is on the impact of environmental aspects such as noise and light or pedestrian flows on the design (ibid.). While Schnabel does not elucidate how these environmental impacts are translated into design parameters, it is unclear whether the setup falls into Love’s category of designs which are merely inspired by environmental parameters or whether it actually responds to environmental issues (and how).

Current CAD software for complex object representation often uses a core representation of scripted, parametric objects. ArchiCAD is a prime example of building information modelling software in which all objects are parametric. The user has the ability to develop custom parametric objects of any scale using the GDL scripting language. Some examples of student projects at an urban scale include housing barracks, public squares, and garden city blocks based on the Barcelona extension (Chase, 2010). While these can produce rather sophisticated parametric designs, they require the overhead of a programming language in which every component must be scripted.

3. A geometric/parametric thinking approach to urban design

The following example illustrates the power of combining geometric and parametric thinking in order to develop a simple and accessible approach to parametric urban design. In the example, SketchUp was used for its accessibility and ease of use.

For the sake of demonstration, the example considers a building bulk on a plot on an urban block where all objects are confined within an orthogonal layout; that is, rectangular shapes and forms which are reflected, shifted or rotated only in steps of 90 degrees. The aim of the example is to illustrate how, by way of a conscious application of simple knowledge of geometry and symmetry, radically different solutions can be generated through very simple steps.
First, we consider an asymmetrical plot (fig. 1).

Fig. 1: An asymmetrical plot

Applying 2D rotation and reflection within the confines of orthogonality, the plot can have 8 different orientations (fig. 2).

Fig. 2: 8 different orientations of the plot

Adding a building to the plot in a similar fashion which always shares the ‘thick’ corner of the plot equally allows for 8 orientations of the building on the plot (fig. 3).

Fig. 3: 8 orientations of the building on the plot

In combination, the 8 building orientations for each plot orientation results in 64 unique instances of building/plot orientations in space. As shown in the two examples, quite different situations can be generated simply from combining (a number of) these 64 different variations (fig. 4 and 5).
Fig. 4: 4 identical urban blocks composed from identical plots with identical building bulks

Fig. 5: 4 identical urban blocks composed from 4 different types of plots with identical building bulks. In this example, there are three instances of plot type a which are unchanged from fig. 4. The remaining plots vary from fig. 4 (plot type a) through rotations of 180 degrees (type b), 90 degrees (type c) and -90 degrees (type d) respectively of the building bulk to the plot.

Due to the geometric qualities of the (one) building bulk in combination with rotations and reflections of the building bulk on the plot, and the plot in space, the example shows how very different urban spaces emerge from a simple change of the combination of building/plot combinations. Hence, as the building bulk in this example has a regular and an irregular side, and as it can be placed across as well as along the length of the plot, a simple rotation of 6 instances of the same building bulk to the plot results in either a very regular or a very irregular morphology of the urban space.

Because of the well-defined relationships of building bulk to plot, plot to urban block and urban block to space, different scenarios can be generated by means of a few steps of rotating or mirroring either the building on the plot, or the plot on the block. It should be noted, of course, that whether one
scenario is preferable to another is a value judgement which is beyond the scope of this paper.

Because the model is made up by components, changing the parameters for each component will reflect for all instances of the component. By nesting components inside other components, a few changes lead to dramatic effects across the model as a whole. In the given example, the building bulk forms the lowest component level in the component hierarchy. The building bulk component is nested inside a plot component which, in turn, is nested inside a site component. In fig. 3, the building bulk component is unchanged relative to all instances of the plot component, while the plot component is rotated (90 and 180 degrees respectively) relative to the urban block component. The urban block component is rotated in steps of 90 degrees relative to space. Fig. 4 differs from fig. 3 only in that the building components have been rotated relative to the plot components in three different ways, resulting in the additional plot component types b, c and d.

It is not hard to see the potential of this approach, however simple it is, when going beyond the limited example given here. Innumerable geometric variations can be achieved alone from introducing non-orthogonal forms and rotations – as well as scaling, and more complex variations of building, plot and block forms. And introducing non-geometric parameters such as materials and colour, or parameters such as vegetation and street layout would expand the scope even more.

In a non-orthogonal organisation, the power of applying geometric thinking becomes even more evident, as in the example below, where the distribution of buildings results from the different organisation of a plot in the shape of a Hirschhorn tile (fig. 6).

![Fig. 6: Two different distributions of buildings resulting from the different organisation of a plot in shape of a Hirschhorn tile.](image-url)
4. Discussion

In urban design, important discussions about the quality of urban space often involve a number of different stakeholders. Before the design reaches the level of architectural detailing, bulk issues such as morphology, density, variation, etc., call for an easy way to test different scenarios in order to foster interdisciplinary evaluation.

To this end, the approach illustrated in the previous section is simple yet powerful. But of course it has limitations. While ‘parameters’ here are simply modelled, a parametric definition of each component is desirable for more complex scenarios (i.e. controlling the number of floors of buildings by means of settings, rather than modelling different building components). This would require climbing some steps up the complexity ladder, as the designer would have to master the skill of scripting dynamic components. Yet, on the other hand, it would allow for easier testing, also by lay people, by choosing from a (predefined) range of different settings. As software applications develop and scripting becomes more intuitive, some simple scripting might still be considered within the range of a simple approach.

The inherent paradox of parametric design is the inevitable trade-off between rule and exception. As long as a model is made up by parametrically related components, everything can be controlled. But as soon as components are unique, the power of parametrics is lost. In real life – and certainly in urban design – designs are likely at some point during the design process to depart, at least to some extent, from the generic quality of parametrically defined components.

The parametric control of a design until the late stages of design is not reserved for advanced applications, however. A clever application of geometric and parametric thinking can take it quite far.

5. Conclusion

Existing specialised software packages are both expensive and require high skills. In addition, they tend to focus either on complex form-making or the negotiation of environmental and legal aspects. This is to some extent reflected also in academia, although some approaches are guided by a critique of the rigidity of traditional masterplans. While a low-tech approach to parametric urban design based on geometric thinking is not appropriate for all design challenges, it does represent a meaningful supplement to the other approaches, particularly in settings where early and conceptual design investigations take place in a collaborative setting.
References

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