ALGORITHMS, AI AND ARCHITECTURE

Notes on an extinction

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Abstract. This paper reports on ongoing research investigating applications and methodologies for algorithms and artificial intelligence within urban design. Although the research recognises not all design is numerically quantifiable, it posits that certain aspects are. It provides evidence of algorithmically derived solutions-in many cases-being as good as those developed by a design professional. I situate the research within a series of examples of design quantification and description. Before discussing practical implementations of algorithmic spatial planning by the co-work start-up WeWork. These projects demonstrate an ongoing narrative to establish spatial syntactical rules for building and urban design. Finally, the paper reports on original research that aims to apply algorithmic space planning to urban design. A work-in-progress, at this stage the finding report on our methodology, preliminary implementation of an algorithmic strategy. It finally presents emerging data pointing to what might happen if the sector does not embrace algorithms and AI.

Keywords. Algorithm; Artificial Intelligence; Architecture; Urban Design.

1. Introduction

This section will situate the research within a historical context of machine supported creativity, before outlining the paper structure.

Perhaps the obvious starting point for this contextualisation is the Industrial Revolution; recognised as an inflection point when machines began to supplant people as a source of making. However, prior to the Industrial Revolution, the Renaissance had-by the 1600's-already created "an unprecedented demand for desks, tables, sideboards, sets of hanging shelves and cupboards, all suited to the housing and display of new possessions" (Hale, 1994, p. 266). During this pre-industrial period, Sennet argues towns were already swelling with artisans to meet public demand for goods (Sennett, 2008, p. 82). He goes onto suggest the industrial revolution of the 1700's was actually a response to an imbalance of supply and demand that already existed. Objects once produced by people are instead reengineered to favour machine production. I would like to draw attention

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to two aspects of this narrative. First, there was already an imbalance in the market and a demand for things to be made faster. The technology solution redressed that imbalance to satiate demand. Second, it was the artisans-the creative sector-who were significantly disrupted in this transformation. In his manifesto Capital, Karl Marx deepens our understanding of this phenomenon. He argues that the machines take the tools from the people, supplanting them as the instruments of making. People are then relegated to machine maintenance, work which is repetitive and creates nothing. This, argues Marx, undermines the sense of self and community.

More recently in the 1980's the emergence of Computer Aided Design (CAD) caused another disruption. No longer were large spaces required for teams of people to manually draw. Simultaneously smaller architectural practices investing in CAD systems could now compete with much larger and more established practices on speed, production and scale of project (Coyne et al., 1996). This caused dramatic change to the industry with large firms shrinking dramatically or going out of business.

Moving forward again to 2000's Building Information Modelling (BIM) was establishing itself as the next disruptive technology. Concurrently practitioners like Frank Gehry and Zaha Hadid were at the forefront of a new geometrically complex form of architecture. Innovation in building form was made possible by their appropriation of emerging parametric and procedural forms of computer modelling software such as CATIA, Rhino and Grasshopper. Even the introduction of the mobile phone had an impact of the dynamics of design and construction (McMeel, 2009).

This short contextualisation is to demonstrate that the creative industries are not insulated or protected from technological change. Indeed historically they have been significantly susceptible to disruption from less sophisticated technology that the current wave of robotics, algorithms and AI. It is useful to reflect on this historical narrative in light of current speculation on robotics and Artificial Intelligence. Most of which points to disruption of 'white-collar' and service sectors (Shewan, 2017; West, 2015). What this paper hopes to show by stepping through a series of examples is that significant aspects of design work can be clearly quantified and thus automated. In particular instances the algorithmically automated designs are as good at those derived by experts.

This paper starts by first reviewing the historical body of work that approaches spatial design systematically. It then looks at current research deploying algorithmic methods for office design. Second we unpack algorithmic methodology and speculate how it could be applied it to urban design. Finally we analyse our results to assess if an algorithmic methodology can be used successfully for urban design.

2. Background

This section will work through a series of computational methods that position fundamental aspects of design as explicit, numerically describable and verifiable. We will discuss them under the three themes of Space Syntax, Multi Objective Optimisation Problems and Algorithms. The aim is to recognise the historical work that exists around establishing rules for spatial design and where this original research project will build upon it.

2.1. SPACE SYNTAX

The concept of Space Syntax emerged in the late 1970's and is largely credited to Bill Hillier (2007). It posits space can be described by being separated into discrete parts with explicit connections between these parts. We are perhaps most familiar with this concept through design guides like the RIBA Metric Handbook (Littlefield, 2008). Which contains derivations of space syntax diagrams outlining the spaces and connectivity required for a variety of building types such as hospitals, airports and TV studios. These complex buildings require people to move in explicit ways and particular functions to be proximate to each other. Thus, space syntax diagrams are useful to help design complex buildings that work. It has also been used as a key tool to determine walkability (Watts, Diaz Moore, Ferdous, & Burns, 2015). Importantly the idea of space syntax does not include form, it is explicitly about describing specific space and connectivity.

In parallel the architect and design theorist Christopher Alexander released the seminal work A Pattern Language (Alexander, Ishikawa, & Silverstein, 1977). This extended the proposition of Hillier to suggest different parts of our environment could be defined as specific patterns. Patterns existed at different scales and could be nested within each other. The concept of nesting patterns within each other allowed for a significant increase in the potential for complexity. While simultaneously the discrete pattern principles could continue to be understood. This is a concept that continues to be used in parametric schema and object-oriented computing (Burry, Burry, & Davis, 2011).

2.2. MULTI OBJECTIVE OPTIMISATION PROBLEMS

MOOP's are a strand of mathematics that posits in any sufficiently complex system multiple objectives need to be optimised simultaneously. In such a system no single solution exists that simultaneously optimises each objective. It has been used in various fields including finding solutions for traffic planning, radiation therapy and conceptual building design (Bitterman, 2011; Perederieieva, Ehrgott, Raith, & Wang, 2016; Raith, Wang, Ehrgott, & Mitchell, 2014). MOOP's build on Hillier and Alexander's concepts by acknowledging a significantly higher level of complexity. It also recognises the impossibility of optimising for all objectives.

2.3. ALGORITHMS

The widespread use of graphical software such as Revit and Rhinoceros have allowed for the inclusion of complex programming within the design domain. This space is dominated by the creation of complex building forms. However, there is a clear shift to apply these powerful computational tools to other problems; such as the complexities of building planning.

Several different approaches can be identified which we will discuss under the themes decision support and decision making. In the first category, 'decision support' algorithms are used to provide decision support this has been investigated by Bitterman (2011) and Nagy et. Al. (2017) where algorithms are used to identify a solution space, a set of solutions that designers then interrogate and discuss with clients, before making a final selection. The New York based co-working provider WeWork is investigating the use of algorithms for office planning (Anderson, Bailey, Heumann, & Davis, 2018). Where algorithms provide a selection of layouts that meets their design requirements. WeWork operates thousands of co-working spaces, and have been able to compare their algorithmically derived solutions with architecturally derived ones. The second approach is 'decision making,' perhaps more contentious as it has less designer involvement. It involves describing complex spatial arrangements in an Excel spreadsheet. This extends to detailed and highly specific spatial relationship, zoning and spaces that require adjacency. The only geometric input required is the building boundary and the algorithm creates a spatial design (Das, Day, Hauck, Haymaker, & Davis, 2016).

In summary, we have reviewed some historical and current approaches to computation and design that seek to view aspects of design as a rule-based organisational and optimisation activity. With the exception of Bitterman's work the research is dominated by systems for two-dimensional spatial planning, rather than 'design.' Spatial planning in most cases is comprised of a large number of explicit factors that the designer or designers are attempting to optimise. For the purpose of this research, we are particularly interested in WeWork's methodology. It focuses on fitting repetitive and regular geometric shapes (desks) into a bigger space (an office). This has obvious parallels with suburban planning, which also involves fitting many rectangular shaped building plots into a larger site. The following section will unpack this method and explain how it will be used.

3. Research

The approach to the research project was to posit that office and urban design had a number of similar principles; fitting things efficiently into a space, or 'packing' as it is sometimes called. WeWork's designers have several tried and tested methods for fitting desks into a space. For example, one approach is to fit desks around the edge and then start filling in the rests of the space with back to back rows. Like office planners, urban planners have tried and tested approaches for efficiently subdividing large plots of land into sub-plots for selling. By automating these approaches it creates the potential for increasing efficiency and speed of the designing process, or it can allow designers to spend more time on higher-level, more complex design problems and less on mundane repetitive tasks.

3.1. METHOD

The project applies WeWorks methodology from office planning to urban planning. First, WeWork approach planning initially as two dimensional space planning exercises. The general aim is to strike a balance between maximum efficiency-which maximises financial return-and comfort. The planning is based on quantifiable values, for example, required dimensions and areas of a desk and a seat. In most cases, as previously discussed, tried and tested approaches are known and result in the most efficient arrangements. It is when unusual shapes or boundary conditions exist that expert knowledge is required and higher level problem-solving is required.

Second, WeWork's algorithms return multiple solutions, WeWork theorises their occupancy data from thousands of offices can be used to train an Artificial Intelligence to identify which solutions would be most popular within the context of their business. This research project initially focuses on the development of algorithms that mimic typical urban space planning strategy.

This phase of the project focuses on mapping the first step of WeWork's work onto urban planning. We develop algorithms to subdivide a site into smaller blocks and populate those blocks with plots for housing.

3.2. THE PROJECT

The first stage of the project was to understand the 'base unit.' In this case we focused on the rules and regulations around detached suburban housing. One of the primary drivers for this research was investigating what processes with the planning, design and construction of housing could be improved with automation. There are significant housing issues within New Zealand, this is part of ongoing research to explore how it might be improved. With than in mind the project worked within the most common context of development; the planning of detached housing on green or brownfield sites.

The Auckland Unitary Plan has explicit rules regarding minimum distances required between a house and its plot boundary, and there are explicit height limitations (Figure 1).

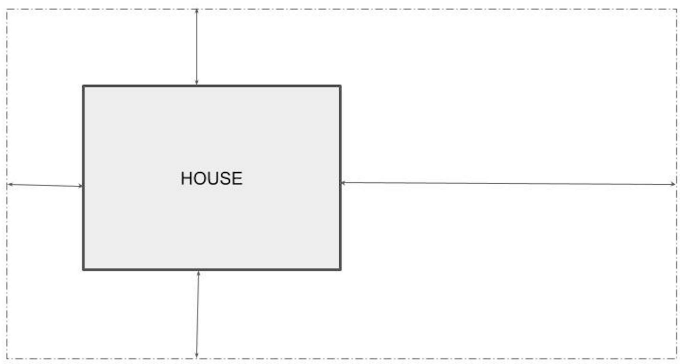

Figure 1. A building plot: a detached house footprint and minimum boundary requirements.

3.3. THE ALGORITHMS

The researchers began with the base unit of a typical detached house footprint and the minimum distance to front, back and side boundaries. This was created within a parametric design software that enables size of the house to be changed and the boundary dimensions would automatically update. The initial approach was to create blocks from these individual building plots. Then blocks would be built up to fill what we call a super-plot (Figure 2). In a similar strategy to WeWork we are starting with the smallest know base unit and working backwards.

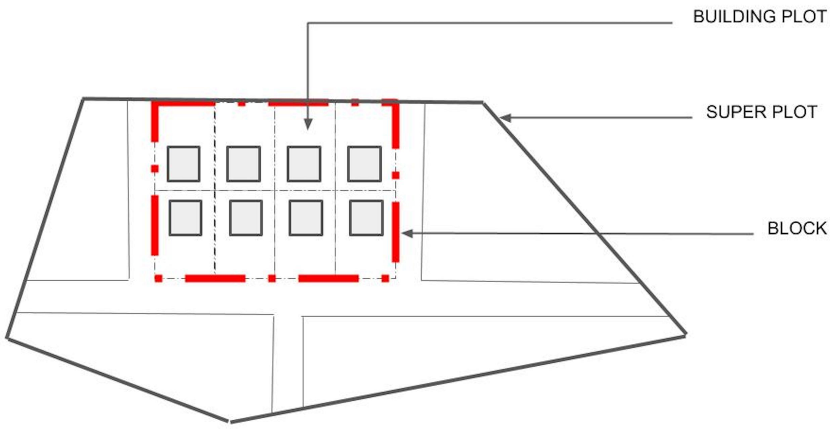

Figure 2. A building plot, block and super-plot.

The software chose was the Rhinoceros 3D modelling software with the parametric Grasshopper plug-in. This enabled us to apply Python scripted algorithm to simple geometries (Figure 3). As the work developed particular configurations were identified that were not desirable. For example where a block was rectilinear the subdivision was precise and accurate. Where it was not unusual overlaps or geometries were created. In these cases it was possible to identify the specific undesirable arrangements and build into the algorithm contingency to avoid them. At this stage of the research we have developed a proof-of-concept that enables simple subdivision based on the Auckland Unitary Plan (Figure 4).

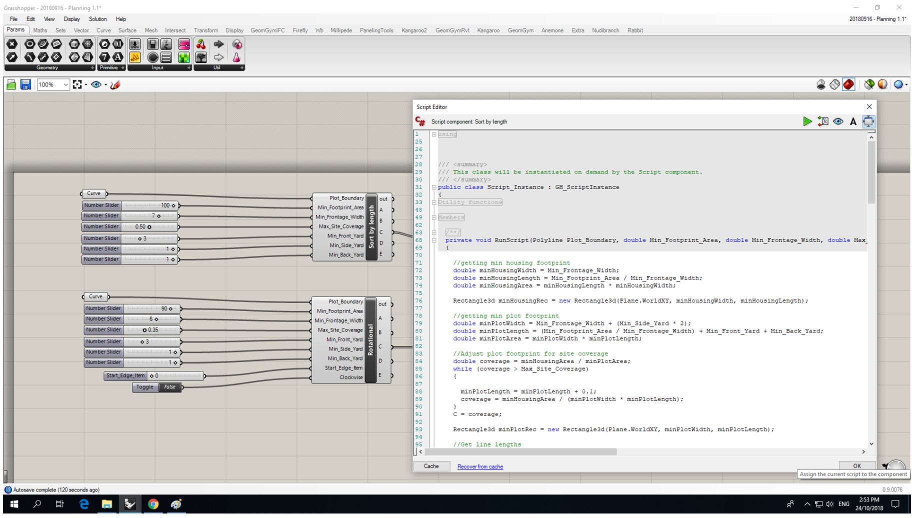

Figure 3. Grasshopper including Python script.

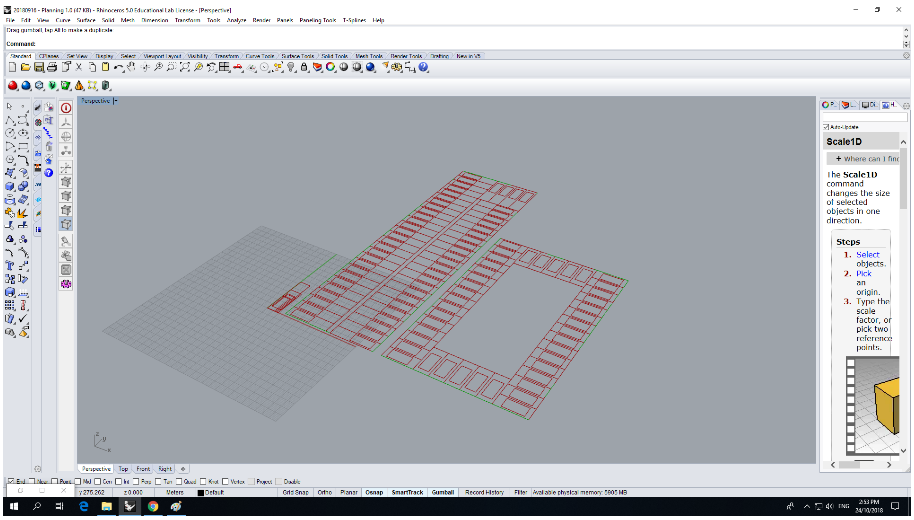

Figure 4. Super-plot algorithmically subdivided in blocks and house plots.

3.4. FUTURE

The next stage of research will create a simple working algorithm that can be applied to basic non-rectilinear shaped super-plots. Mapping WeWork's methodology the focus will be to compare how the algorithms perform against pre-existing developments subdivided by experts.

The rules and regulations for planning a suburban development are more complex than an office space. Also, while WeWork's base unit of a desk and chair does not change, for a suburban subdivision there are various base units such as semi-detached housing, detached housing, duplex, terrace, apartments etc. It is common for subdivisions to have a combination of several of this typology. As a way of formally addressing this complexity we propose the implementation of a standard machine readable form of these regulations. Using a standard such as LegalXML we plan to encode specific aspects of the regulations such that the algorithm can create plots and blocks that conform to site specific regulations from region to region and country to country.

Finally, the research will eventually explore if it is possible to gather data to train an appropriate AI-similar to WeWork's hypothesis-to return assessments on desirability of different algorithmic solutions.

4. Analysis

Although the research is in an embryonic stage there are a several aspects to note. First, WeWork demonstrated in approximately 77% of cases their algorithms were as good as human designers. When humans were superior to algorithms it was in situations where the rules could-or needed-to be bent to gain advantage. We found we could implement our own algorithm for urban space planning. In addition-when applied to rectilinear shaped subdivisions-they were simple and could execute subdivision accurately and quickly.

The issues of desirability or quality is harder to determine. WeWork have design guidelines to help their designers maintain consistency across their office spaces. Their algorithms were developed to adhere to these guidelines so that-in principle at least-the algorithmic solutions were not a significant departure from the human derived result. Recalling that efficiency is key to WeWorks success, fitting as many desks into a space as possible is a high priority. Again this is a principle applicable to urban space planning. At the time of writing our research had not evolved to encode design principles into the subdivision logic.

Furthermore, efforts by WeWork to understand office design, occupancy and management have resulted in some important statistics. Started in 2010, by 2018 is has become the biggest private property occupier in London (Williams, 2018); a market they did not enter until 2014. Like many 21st Century companies, they are innovating and applying new methods to existing sectors. Underpinning WeWork's success is their use of data, something the average architectural or property developer does not engage with. The senior researcher at WeWork asserts if you are not designing with data you are not designing (Murrye Bernard, 2018).

Finally, WeWork is a new form of business, a hybrid of designers, property and facility managers, they design and manage the occupancy of office space. The occupancy data gathered informs future office design. Indeed the spin-off service 'Powered by We' offers to build and operate your office space for your business. They again are aggressively moving into new territories and disrupting traditional businesses and modes of practice. Their new mode of design/management practice has dominated London in less than 5 years.

5. Conclusions

In this paper we have outlined a methodology appropriated from WeWork and applied it to urban design. We have demonstrated that an algorithmic approach to the subdivision of suburban planning is possible. The focus has not been on form of complex geometry it has instead to apply powerful computational tool to the regular and repetitive aspects of this specific design space. Making planning faster and simultaneously allowing designers more time to concentrate on higher-level design problems. It has also drawn attention to new modes of practice for spatial design and management that challenges conventional business models. The paper began with a provocation, an exhortation on extinction. The hybrid operational services provided by WeWork is new, and it provides a single point of service that meets the needs of the market better than the current fragmented services design, construction and management services. It may mark the beginning of the transformation of architecture to a platform economy. If so, we are at the vanguard of a technological change that will have significant consequences for the sector.

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References

Alexander, C., Ishikawa, S. and Silverstein, M.: 1977, *A pattern language : towns, buildings, construction*, Oxford University Press, New York.

Anderson, C., Bailey, C., Heumann, A. and Davis, D.: 2018, Augmented space planning: Using procedural generation to automate desk layouts, *International Journal of Architectural Computing*, **16**(2), 164-177.

Bernard, M.: 2018, “The Interloper: WeWork Upends the Conventional” . Available from <ht tps://www.architectmagazine.com/practice/the-interloper-wework-upends-the-conventiona l-architecture-firmextbackslash_o?fbclid=IwAR19ty3ego0WBGe7N5Kb6vZRJCFqEJY69 CImXGI4luYpJG6kh8esnUS3WWI>.

Bitterman, M.: 2011, Sustainable conceptual building design using a cognitive system, *Proceedings of the 14th international conference on Computer Aided Architectural Design*, Liege, 297-313.

Burry, M., Burry, J. and Davis, D.: 2011, Untangling Parametric Schemata: Enhancing Collaboration through Modular Programming, *CAAD Futures 2011: Designing together*, Li\‘ege, Beligum.

Das, S., Day, C., Hauck, A., Haymaker, J. and Davis, D.: 2016, *Space Plan Generator*, ACADIA.

Hale, J.R.: 1994, *The Civilization of Europe in the Renaissance*, Fontana Press.

Hillier, B.: 2007, *Space is the machine: a configurational theory of architecture*, Space Syntax.

Littlefield, D.: 2008, *Metric handbook*, Routledge.

McMeel, D.: 2009, *The Artistry of Construction*, Ph.D. Thesis, Edinburgh University.

Nagy, D., Lau, D., Locke, J., Stoddart, J., Villaggi, L., Wang, R., Zhao, D. and Benjamin, D.: 2017, Project Discover: An application of generative design for architectural space planning, *SimAUD 2017 Conference proceedings: Symposium on Simulation for Architecture and Urban Design*.

Perederieieva, O., Ehrgott, M., Raith, A. and Wang, J.Y.T.: 2016, Numerical stability of path-based algorithms for traffic assignment, *Optimization Methods and Software*, **31**(1),

53-67.
Raith, A., Wang, J., Ehrgott, M. and Mitchell, S.: 2014, Solving multi-objective traffic assignment, *Annals of Operations Research*, **222**(1), 483-516.
Sennett, R.: 2008, *The Craftsman*, Yale University Press, New Haven.
Shewan, D.: 2017, “Robots will destroy our jobs – and we’re not ready for it” . Available from <https://www.theguardian.com/technology/2017/jan/11/robots-jobs-employees-artificial-intelligence>.
Watts, A., Diaz Moore, K., Ferdous, F. and Burns, J.: 2015, Neighborhood integration and connectivity predict cognitive decline in older adults with and without Alzheimer, *Gerontology & Geriatric Medicine*, **1**, 1-9.
West, D.M.: 2015, “What happens if robots take the jobs? The impact of emerging technologies on employment and public policy” . Available from <https://www.brookings.edu/wp-content/uploads/2016/06/robotwork.pdf> (accessed 1st January 2019).
Williams, A.: 2018, “WeWork becomes central London’s biggest office occupier” . Available from <https://www.ft.com/content/40a87044-ff97-11e7-9650-9c0ad2d7c5b5>.