O- 0266

Computation as a Driver for Quantitative Design Decisions

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Abstract

Sunlight in public spaces shapes the character and rhythm of cities, they have the power to control how people utilize them. Major cities councils such as Sydney and New York councils have adjusted their planning regulations in the last few years to limit the impact of new developments on their public spaces. Recently imposed guidelines, such as the State Environmental Planning Policy No65 in New South Wales (SEPP65) and No Additional Over-shadowing legislations in Australia, have challenged design methods; requiring residential buildings to be designed based on more prescriptive environmental performance requirements. This paper looks at a computational design method developed using quantitative solar analysis to measure planning compliance and the impact of planning proposals on public spaces and reduce the overshadowing impact on surrounding residential buildings and public spaces. A computational design method has been developed based on environmental and financial metrics to satisfy both the planning controls and the client's commercial interests so as to produce rapid design alternatives.

Keywords: Environmental computation; Performance Driven design; Quantitative design decisions

1. Introduction

Both internationally and locally within Australia, we are seeing the continual development and modification of planning legislation and guidelines in an attempt to keep pace with the rapid changes in urban development. Legislation such as the UK's 'Right to Light', and state guidelines within Australia such as the State Environmental Planning Policy No65 (SEPP65) in New South Wales (SEPP65 2015), have been established in an attempt to improve the quality of developments in relation to building performance, and amenity. These regulations set design guidelines for performance aspects such as solar and daylight access within residential apartment developments.

Performance requirements have shaped a new generation of design practices that prioritize data-enabled design processes so as to provide quantitative solutions (Alhadidi et al 2016). As a result, planning legislation is shaping building forms. This can be seen in projects such as the Solar Carve Tower in New York by Studio Gang architects (Rosenfield 2012), and BVN's Pitt St development in Sydney (Johnson 2015).

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2. Antecedents and what is missing

The current computational analysis workflow practices utilised to design and develop compliant residential developments have been inherited from, and shaped by, generations of software tools that follow a process of: Model, Simulate, Analyse. Within this process, designers model a building envelope, or a building, in order to get feedback on the design's performance. Whilst these processes have enabled rapid modelling of, and feedback on, the performance of different design options, not all tools enable flexible implementation of local regulations. Despite continuing development of regional compliance plugins, at present, these tools do not allow the designer to manipulate the design so as to accommodate for the full complexity of site specific regulations and requirements. Within the current use parameters, the tools do not enable the reverse engineering of a design to produce building envelopes that are responsive to site specific neighborhood contexts (i.e. minimum light access requirements for surrounding buildings or restrictions on no additional overshadowing provisions), nor do they enable the inclusion development feasibility data such as financial metrics and apartment mix variations within the model.

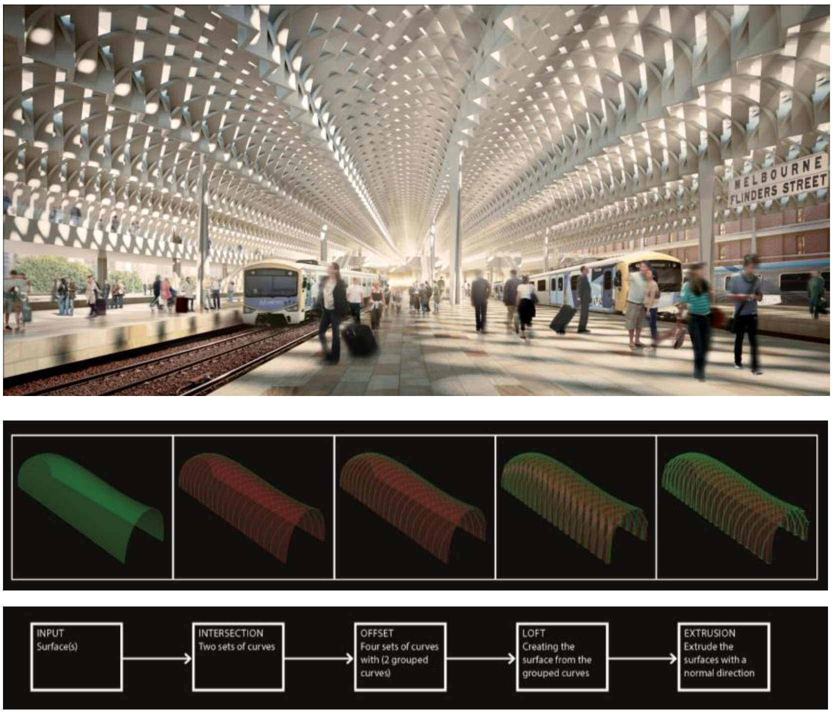


Fig.1. Flinders Station Competition Entry by HASSELL and Herzog de Meuron: The Computational Design logic driven by sun access and daylight concept on platforms level

Whilst such processes enable designers to run a large number of models and iterative design variables that would traditionally not have been feasible due to their complexity and labor-intensive requirements, outcomes are limited by in-built assumptions, lack of guidance and integration within the design process (Hensen and Lamberts 2011), and parameters that are pre-set at the outset. Designers are restricted by software structuring that does not allow full control over performance parameters. Work currently underway, aims to develop a workflow process that enables upfront simulation capacity and the incorporation of a greater complexity of variables within the model. Within this process, Simulate - Generate, the simulation process becomes the feedback loop. Through this reverse engineering process, designers are able to understand upfront what is allowable, enabling the computational design process to inform their designs from the outset. The current process of Model, Simulate, Analyze, then Feedback, doesn't allow for the incorporation of client financial interests, nor for a more complex design oriented understanding of building guidelines and reverse engineering to maximize allowable solar envelopes.

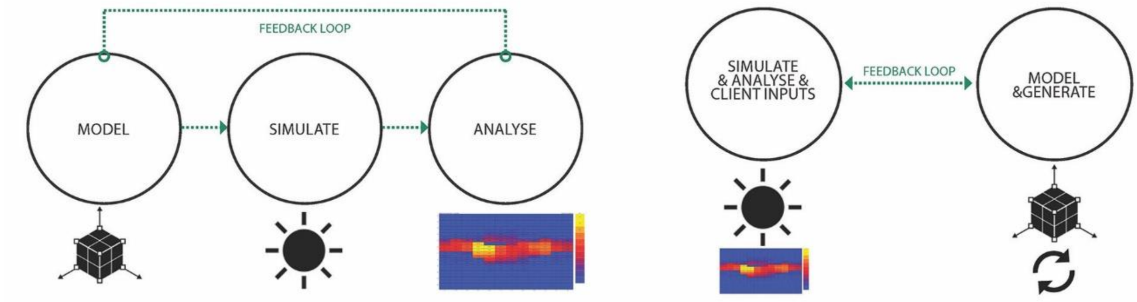


Fig.2. right_ Feedback loop workflow existed in current early stage simulation methods; left_ Proposed workflow: simulation and generative method (Performance-driven)

3. Methods

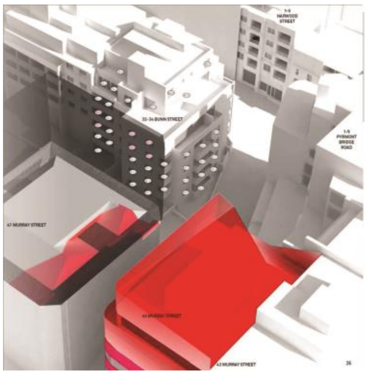
Through the control of building design performance parameters and incorporating the generative methods from the outset, designers are able to maximise building performance objectives. Residential projects are often quite prescriptive in their constraints. Within this process, metrics need to satisfy both planning controls and the client's commercial interests. This paper outlines two case studies in which work process and parametric design tools were developed that allow for quick feasibility assessment based on the number of hours of direct sunlight, the building mass and each individual floor received. The process also utilises an automated optimisation method to comply with planning controls, assess project financial feasibility, and allow for a better distribution of the apartment mix.

The Apartment Configuration Generator Tools were based on the following parameters:

- Living rooms and private open spaces for at least 70% of apartments in a development should receive a minimum of three hours of direct sunlight between 9am and 3 pm in mid-winter (in dense urban areas a minimum of two hours may be acceptable).
- Limit the number of single-aspect apartments with a southerly aspect (SW-SE) to a maximum of 10% of the total units proposed.
- 60% of residential units should be naturally cross ventilated.

3.1. Impact assessment and reduction

45 Murray Street, Pyrmont, is located in a prominent position to the west of the Sydney CBD. The existing site was underdeveloped, relative to its surrounding context. To examine the potential for increased site yield, a comprehensive urban design and computational analysis were prepared that evaluated the site and surrounding context. Solar access impacts of the proposed maximum building parametric envelope and an automated shadow assessment tool were developed that enabled a 'simulation first' process of neighbouring sites and the proposed site.



	Current	Proposed	Reduction	Reduction
AW3.4	148 minutes	120 minutes	28 minutes	18.9%
AW3.5	128 minutes	120 minutes	8 minutes	6.3%
AW4.4	148 minutes	120 minutes	28 minutes	18.9%
AW4.5	148 minutes	120 minutes	28 minutes	18.9%

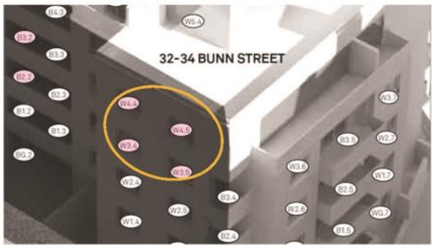


Fig.3. Apartment references used for solar access analysis at 32-34 Bunn Street.

This information then fed into the design generation process. The chart demonstrates the existing amount of solar access to each nominated window and the affect (if any) of the proposal on solar access based on the solar access requirements defined by City of Sydney (SEPP65, 2015).

The computation process generated using Grasshopper and C# to calculate sun vector access to liveable spaces can be summarised as the following:

Step 01 Simulate the solar intake for all surrounding sites and get existing performance data.
Step 02 Maximum building envelope.
Step 03 Maximum building envelope carved to maintain 2 hours access to neighbouring 32 Harwood st.
Step 04 Repeat the process to generate the compliant envelope.

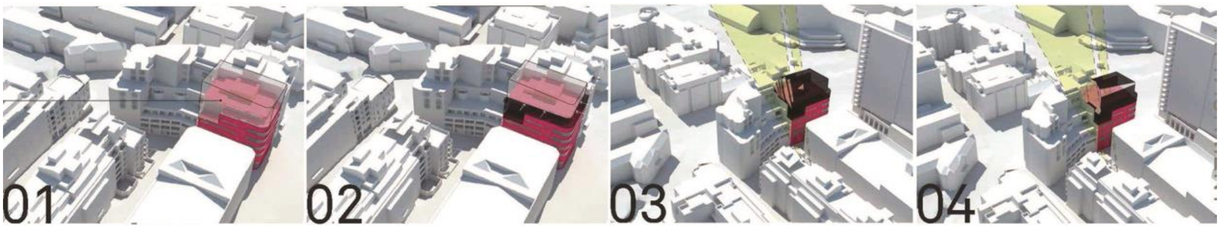


Fig.4. Computational design process to generate the compliant envelope

From the simulation, it was found that less than 70% of surrounding apartments currently receive at least 2 hours of direct sunlight between 9 am and 3 pm at mid-winter. It indicated that six apartments at a neighbouring site would lose between 8 and 28 minutes of sunlight to habitable spaces during mid-winter.

3.2. Apartment combination generator and mix matrix

A selection of pre-defined apartments is chosen as the starting point. These apartments are evaluated based on various criteria, including: SEPP65 compliance, single or double aspect; accessibility etc. Since the orientation of the apartment is not yet known, preliminary results can be ascertained and embedded into the Rhino apartment block using Elefront to establish desired performance requirements. The next step is to deploy these apartments within the building massing. The presented script evaluates the problem mathematically.

Four sliders are established which represent the number of apartment per floor for that particular apartment type. These parameters are known as the 'genomes'. Assuming there will be a maximum of 10 apartment types per floor, the slider can be set to have a minimum value of 0, and a maximum value of 10 (11 possible genome states). Since there are four sliders, one for each apartment type, this equates to 14,641 possible outcomes.

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As the Brute Force component runs, the script records the genome mix. This list is then exported to Excel. The spreadsheet is then populated with formulas to calculate the total area each genome mix would produce in terms of Net Saleable Area NSA. This area value is used later to determine if that genome mix is suitable. A simple calculation then takes the NSA generated from the massing, and combined with the apartment mix ratio and average area per apartment type, generates the target number of apartments. It is important to note that when calculating these figures, the ratios are based on the total number of apartments, not the total NSA. Therefore, the formula is:

Total apartments = Overall target NSA / ((studio ratio∗studio area) + (1B ratio∗1B area) + (2B ratio∗2B area) + (3B ratio∗3B area))

Once all possible permutations and number of apartments are known, it is possible to filter out configurations that are less desirable. By importing from Excel the total NSA per floor for each genome mix, a comparison can be made between the genome mix NSA and the actual NSA required. The delta between these two values is used as the fitness value. The previous step evaluated apartment mixes on a level by level basis, based on NSA. However, other parameters must also be addressed, such as overall apartment mix. In order to do this, every level must be taken into consideration. Since there are 20 stories in the presented building with 20 possible apartment mixes per floor, this would equate to 100 quintillion possible solutions if the brute force methodology is adopted. This is obviously not viable due to the time it would take to compute all possibilities. The script therefore utilizes Galapagos, an evolutionary solver within Grasshopper to define optimal options.

A simple way of taking a holistic approach to apartment distribution is to calculate the delta number of apartments compared to the brief requirements. By mixing and matching one of the top 20 genome/apartment mixes per floor, it is possible to get close to the brief's requirements. Fitness, therefore, can be defined by the delta number of total apartments compared to the brief. However, this is not always adequate. For example, in certain situations such as a tower, stacking of apartment layouts is desirable. In this scenario, limiting the variations in apartment distribution might be desirable. To cater for this, the script 'penalizes' an overall arrangement based on the number of different mixes it has, essentially ensuring that an apartment mix is repeated throughout the tier/building. By adjusting the various penalty inputs, the user is able to prioritise and customise the fitness criteria.

4. Conclusion

The paper outlined the workflows of two selected residential planning proposals and one commercial development where in-house solar based performance scripts were developed at early design stages and utilized planning controls and design divisions to produce live interactive performance-based designs/models. The paper discussed an approach which is based on quantitative measurements of planning and design decisions. There is a very strong potential that this research can be scaled up to allow for city wide scale measurements that fundamentally challenge the way planning guidelines are being designed. The paper also promote objective design decisions in relation to solar performance with in the proposed development and overshadow impact on the surrounding. A gaming engine was used in later stages of this research to automate the process and reduce the computational power needed by design tools.

One of the limitations of the current research is that no apartment geometry is generated. It is hoped that with further development, the script will eventually be able to automate the placement of apartments based on the apartment mix distribution results and the apartment DNA. This should ensure that apartment layouts don't contradict SEPP65 requirements. Furthermore, it is suggested that the greatest strength in this tool is the ability to financially model prospective designs.

5. Acknowledgement

The work and case studies presented were developed at BVN and HASSELL architects and in collaboration with their teams.

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