GEO-COMPUTATION FOR DISTRICT PLANNING

An Agile Automated Modelling Approach

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Abstract. This paper focuses on developing a novel geo-computational methodology for automating the generation of design options for district planning. The knowledge contribution focuses on the ability of the planners and designers to interact with and override the automated process. This approach is referred to as "agile automated modelling". The approach is demonstrated through a case study in which three adjacent districts are generated with a total area of approximately 1300 hectares. An automated modelling process is implemented based on a set of core planning principles established by the planners. The automated process generates street networks, land parcels, and 3-dimensional urban models. The process is broken down into three steps and users are then able to intervene at the end of every step to override and modify the outputs. This aims to help planners and designers to iteratively generate and assess various planning outcomes.

Keywords. Geo-computation; procedural modelling; GIS; planning automation; neural network.

1. Overview

Geo-computation is at the evolving forefront of research and application. Geo-computational techniques contribute to essential management and processing of data to yield robust insights into the underlying patterns and provide reliable decision-support (Fischer et al. 1998, 2014; Openshaw 1998; Atkinson and Martin 2000; Stouffs and Janssen 2017; Thill and Dragicevic 2018). However, the process of building, displaying, communicating and enabling the addition of rule-based three-dimensional planning is still challenging (Marshall et al. 2019).

Geography has traditionally been forward-thinking regarding the development of algorithms for dealing with large and complex datasets in a timely fashion. The discourse on parallel computing in geography began in the 1990s, leading to the emergence of the subfield of geo-computation (Cheng et al. 2012). Geo-computation, as defined by Openshaw et al. (2000) is "concerned with

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the application of a computational science paradigm to study all manner of geophenomena including both physical and human systems". Building on this, a greater focus needs to be placed on developing algorithms that are parallel in nature and can harness all types of parallelism. Turton and Openshaw termed "Thinking in Parallel" in 1998 but is yet to be fully adopted in the research community (Li et al. 2016).

For urban planners and designers, geo-computation can be applied in order to automatically generate large scale design proposals following various rules and guidelines. Such automated modelling approaches support rapid iterative virtual prototyping, in which a large number of design options can be generated and evaluated. However, automation also has its down-sides. Heumann and Davis (2019) hypothesize that the adoption of advanced automated processes in practice requires improving the experience for human designers as much as it requires focusing on improving the performance of algorithms. After observing the designer's workflow, they identify tasks that should be automated and propose methods for ensuring tools integrate into – rather than interrupt – existing processes.

We believe that in order to make automation useful for tasks such as planning, agile approaches have to be developed. In software development, the 'agile approach' is a human-centred software development method that can respond to rapidly changing end-user requirements through flexible iteration and gradual development (Martin, 2003). Agile automated modelling applies a similar approach to modelling design proposals. The aim is to allow designers to leverage high levels of automation while at the same time still maintain a high level of control over the outputs that are generated. We refer to this as *agile automated modelling*.

The approach encourages designers to create their own customised automated processes for generating design options by chaining together a variety of different GIS and 3D parametric modelling tools. However, for any automated process, there will always be special input cases in which the outcomes do not match the designer's expectations. Attempting to 'fix' such automated processes is very difficult, as the number of 'special cases' can be significant. Therefore, in the proposed approach we break the automated process into a series of smaller steps and allow the designer to intervene and to modify the outputs after each step. This approach has two key benefits for designers. First, the task of developing the automated generative processes is much easier, since all the special cases do not need to be resolved. Second, the ability to intervene and modify outputs gives designers a high level of control over the final output.

Following this philosophy, we have developed an agile automated modelling approach for district planning. The approach has been developed by working on a specific case study in Singapore. Section 2 gives an overview of the agile automated modelling approach and its application within the case study. Sections 3 and 4 briefly discuss future work and draw conclusions.

2. Agile-Automated Modelling Approach

The proposed agile automated modelling approach strives to create a synergetic relationship between the human designer and the automated processes. The aim is to create a process that is highly automated but that nevertheless gives the designer a high level of control at various points in the process. In the proposed approach, the human designer oscillates between two modes of working, which we refer to as 'generating' and 'modifying'. In the generating step, the designer applies automated processes to generate large and complex datasets. In the modifying step, the designer will selectively modify those datasets to account for aspects that were not coded into the automated process. Finally, the modified output can then form the input into the next generating step, thereby creating an automation chain.

2.1. CASE STUDY

An agile automation modelling approach is tested with a case study in Singapore, generating three adjacent districts with a total area of approximately 1300 hectares. The district generation is conducted in a consecutive three-part geocomputation methodology (see Figure 1).

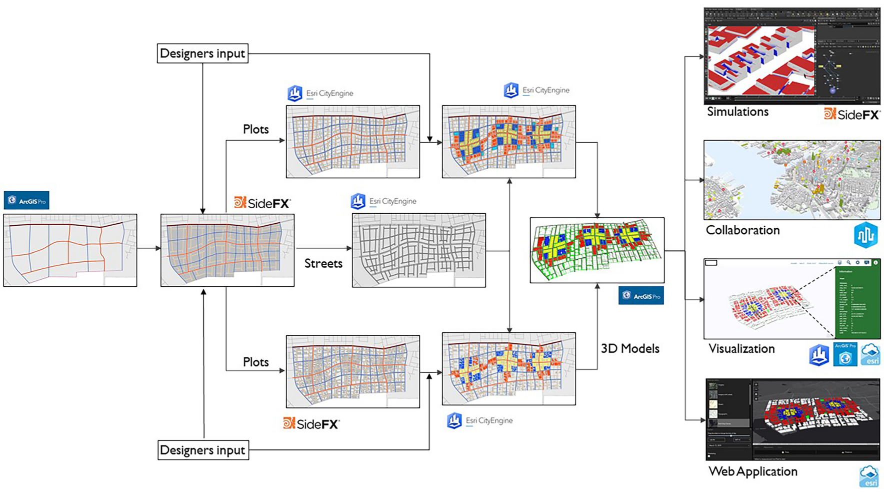

Figure 1. Overall workflow explaining the proposed agile-automation approach for district planning.

The three parts are: Part 1- Procedural Modelling using Houdini(SideFX), Part 2- Rule-Based Modelling using CityEngine and Part 3- Performative Modelling using various platforms. Procedural Modelling method starts with a district boundary, pre-existing conditions (roads) and guidelines to automate generation of street networks, plots (land parcels) and buildings. This is generated around nodes (primary and secondary) which are controlled by designers. At any point, a designer can intervene and modify the positions of these nodes. Eventually, gaining control over the output. The designer then takes the output of part-1 to

Rule-based modelling for developing a detailed model. The designer in part-2 gets further opportunities to explore many possibilities within this well-defined context before moving ahead. Finally, Performative modelling takes the generated district output of part-2 for further evaluation.

A district planning boundary definition is considered as a user-defined input. We have considered existing roads like CAT-1 (expressway) and CAT-2 (major arterial road) as inputs. Street widths and dimensions are pre-defined as per code of practice for road works by Land Transport Authority (LTA). Categories of roads are distinguished with varying widths and relationships to the development alongside it. The district is procedurally developed as per the district planning methodology which takes place on different levels, namely, precinct (800m), sub-precinct (400m), street and plot (see Figure 2). We connect these levels retaining an inter-dependency. This makes it easy for a designer to intervene and make any number of iterations.

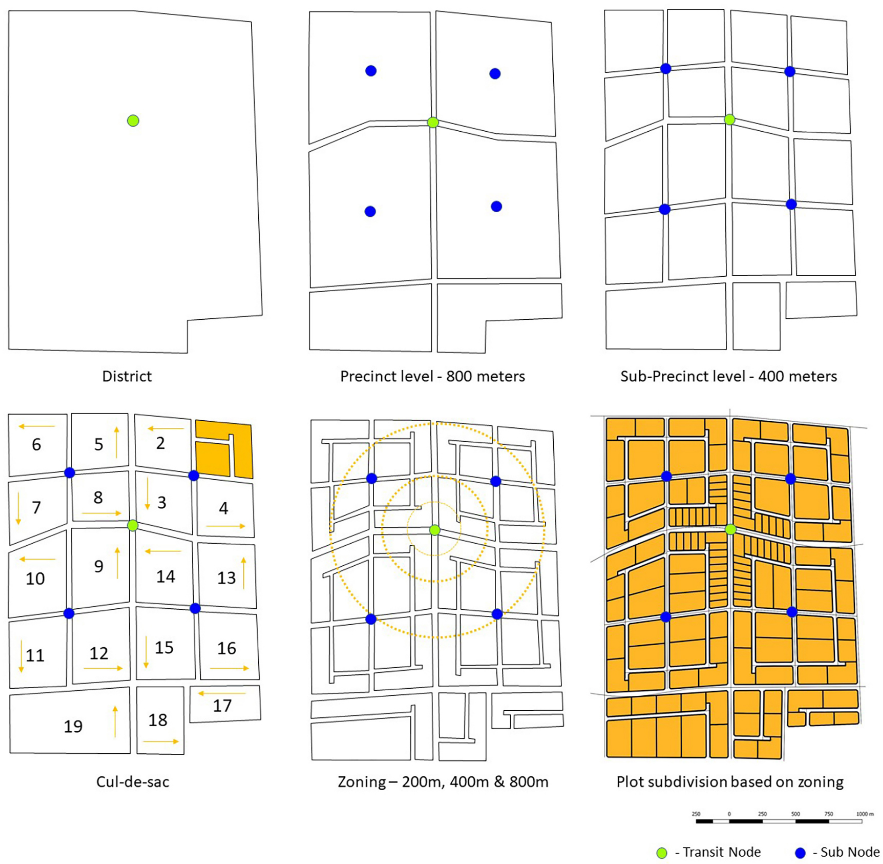

Figure 2. District planning methodology.

2.2. PROCEDURAL MODELLING

In the Procedural modelling method, Houdini (SideFX) software is used to create procedural modelling network for generating scenarios. Districts with roads, plots (land parcels) and buildings are generated as per the predefined planning principles. A district is generated around several urban nodes namely primary (major public transit node like mass rapid transit stations and bus interchanges) and secondary (identified sub-centres of portions of the district). The procedural modelling occurs in three major steps - a) Generating street networks b) Subdividing the plots and c) Identifying land use type. Subsequently, geometric data for roads, plots and buildings is created which carries processed information as attributes.

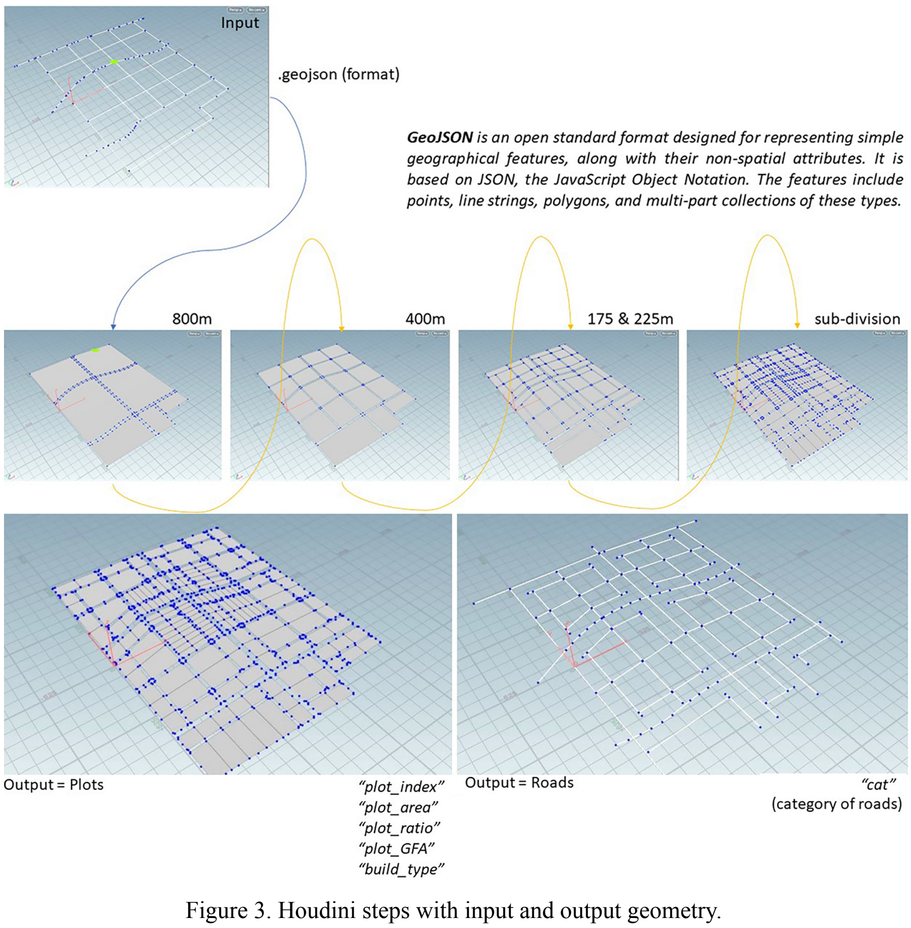

Figure 3. Houdini steps with input and output geometry.

With this information, incremental road centrelines are created. The distances between roads are generated following the planning principles. Clusters of land are formed following the road offsets and beyond the road reserve line as defined by “LTA-code of practice”. Subsequently, plot subdivisions are applied onto clusters based on their distance to the primary node, land-use type, and minimum-maximum plot sizes (in terms of area and boundary length). Land use types are formulated as per plot proximity to the nodes. We have translated instructions from planning principles about mixed-use and amenity to create land-use type. Subsequently, buildings are extruded from each plot based on the specific plot ratio, gross floor area and land type assigned. Later, in the Rule-Based Modelling step, an alternative iteration is presented for building generation. The plot ratio and gross floor area are assigned based on the distance from the transit node.

Finally, the outputs of the Procedural Modelling step are generated separately as roads, plots, and buildings (see Figure 2). Each of these outputs carries additional information, stored as attributes attached to geometric entities. For instance, the road centrelines have the attribute “category_of_road”; the plot has “plot_ratio”, “gross_floor_area”, “plot_type” and “area”; and buildings have “elevation” and “total_height”.

The input and output of the procedural modelling in Houdini is provided in the GeoJSON file format (.geojson). GeoJSON is an open standard format designed for representing simple geographical features, along with their non-spatial attributes. The features include points, line strings, polygons, and multi-part collections of these types. In our methodology, the inputs are the district boundaries and existing major road centrelines as line strings and primary-secondary nodes as points (see Figure 3). The outputs are road centrelines as line strings, and plots and building footprints as polygons. Using “JSON to Feature Tool” in ArcGIS Pro, we have converted these GeoJSON output files to ERSI file formats for subsequent use in CityEngine in Part-II.

2.3. RULE-BASED MODELLING

The Computer-Generated Architecture (CGA), is a unique programming language that is used to generate architectural 3D content. Based on the CGA syntax, the methodology was constructed complying with the existing guidelines established by local authorities for roads and plots. Street CGAs are applied on road centrelines to create detailed street models, incorporating pedestrian pathways, bus and cycling lanes, trees and vegetation, and street furniture and lighting. Similarly, plot CGAs are applied to generate building massing taking into account planning regulations and guidelines.

Through the specification of building parameters such as floor to floor height, several buildings in a plot can be tested iteratively by users with the “Inspector” tool in CityEngine. Buildings generated by CityEngine serve as alternative feedback to the part-I building output and aid in the specific plot descriptions.

Figure 4. 2D and 3D output generation of 3 Districts.

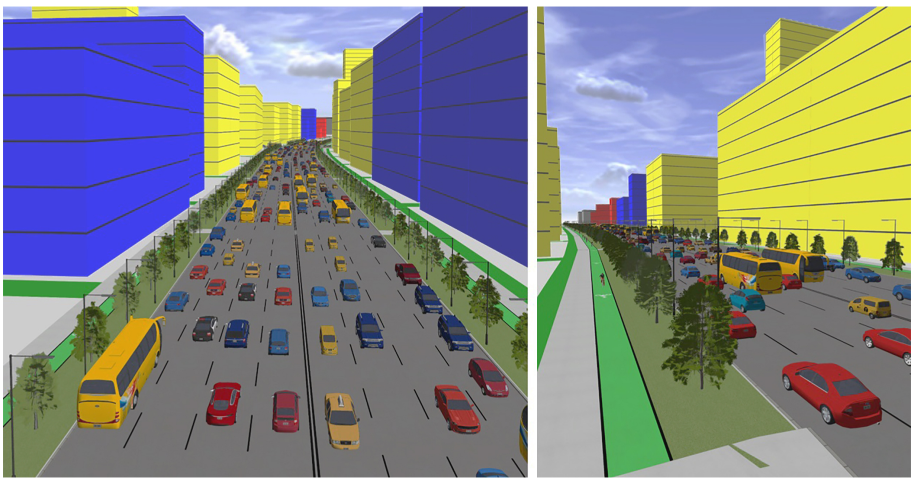

Figure 5. Detailed street models generated using CGA.

2.4. PERFORMATIVE MODELLING

In the third part of our Geo-computation methodology, the generated 3D urban models are exported to various platforms (CityEngine, ArcGIS Pro, Houdini, WebGIS) for analysis and visualisation. This step helps designers to visualise the models and to further evaluate the models using a variety of analysis methods.

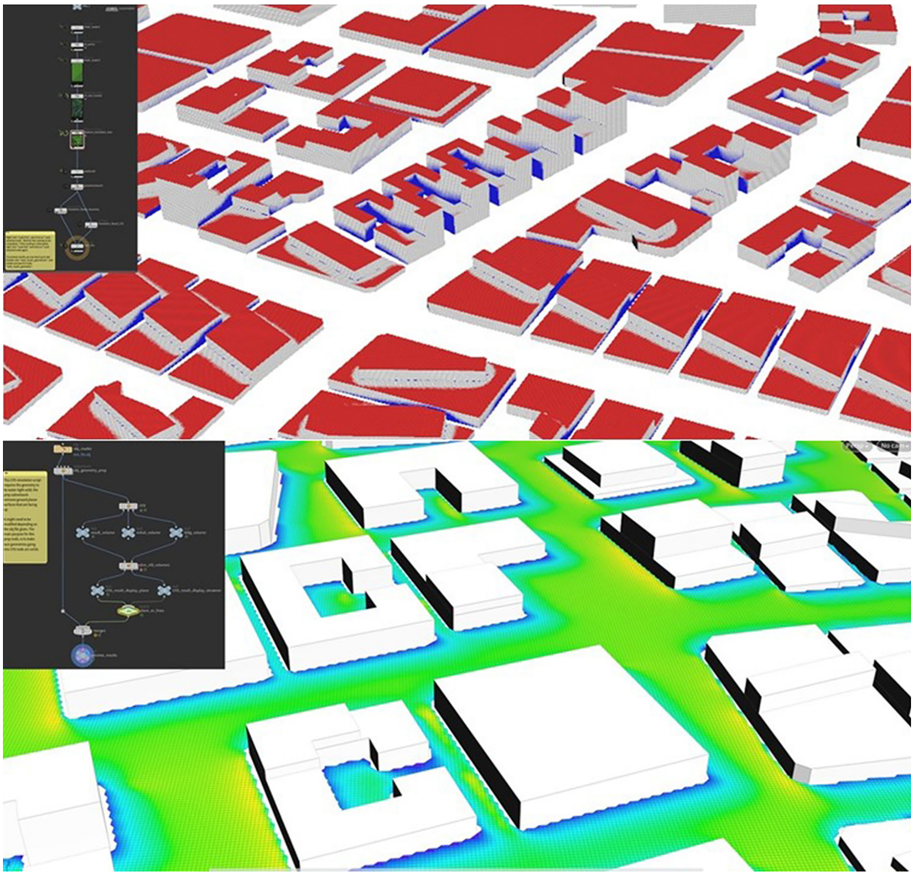

Figure 6. Solar radiance and wind simulation results in Houdini.

The CGA embedded model can be converted to a multipatch data type (feature in .gdb file geodatabase) in CityEngine. This 3D data with all attribute information is converted to CityGML (text format) using ArcGIS Pro. A CityGML file or .OBJ file can be taken to Houdini for running simulations like solar irradiance and CFD (Computational Fluid Dynamics) wind analysis for the buildings. CityGML can carry textures with attribute information and can be easily visualised back in GIS platforms. In our methodology, the simulation results are well documented in the files as we maintain our workflow, avoiding data loss. Figure 5 shows the results of the model simulations in Houdini. We also explore the possibility of using this methodology to support planning using Form-Based Codes (FBC), i.e. regulating land development to achieve specific urban forms.

Using the CityEngine model export option of .3ws (CityEngine WebScene format), the model can be published on web platforms (see Figure 6), while ArcGIS Pro can publish the WebScene directly to ArcGIS Online. WebGIS platforms are used to visualise data with symbology and pop-ups for non-GIS experts. This step makes it easier to visualise, run a query and go through the urban prototype model for further evaluation.

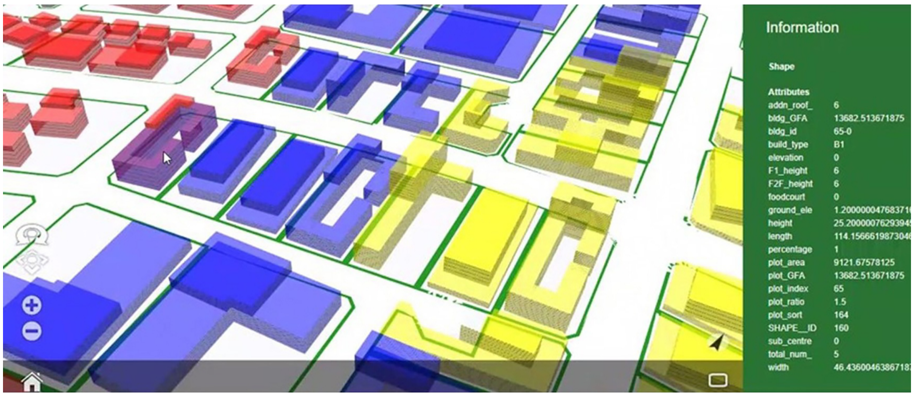

Figure 7. CityEngine webscene viewer.

3. Discussion

Overall, the research has resulted in the development of a geo-computational methodology for automating the generation of scenarios for district planning. The case study demonstrates how planning tasks can be seamlessly automated with an approach that is pragmatic and grounded with the designer's and the planner's involvement. A wide range of software was tested, with an aim to improve the ability of city planners and designers to interact with and override the automated procedures. The methodology enables users to combine the merits of the software together, improving the efficiency of the process and the efficacy of results. The research reports a methodology that helps users to iteratively generate and assess outcomes of planning tasks. The research also demonstrates an exploratory means to the planning process. With this exploratory path, there comes the question of standardization of planning principles. Although calibration is an essential part of the planning decision-making process, it is not covered here given the focus of this paper is on the methodology of automation.

4. Conclusion

The broader aim of this research is to develop a practice-oriented approach to create planning support systems, with the specific aim to improve the synergy between the tools and the workflows in practice. The research started by first mapping out end-to-end workflows that exist within planning practices. From these workflows, a modular and flexible approach is derived and developed on top of an existing infrastructure that is already well established within the planning practices. The proposed *agile automated modelling* is demonstrated using a three-part geocomputation methodology - Procedural Modelling, Rule-Based Modelling and Performative Modelling. It enables the effective intervention of users which satisfies the requirements of flexible iteration and maintains a high level of control over the output.

Furthermore, the development of automation procedures needs to acknowledge the point of view of planners and designers. This requires further exploration of potential methods to provide this inclusivity in automation. Simultaneously, ways of visualising 3D data have to be evolved towards engaging dialogues among decision-makers who can think and plan for the complexities of future cities.

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