Civil Systems Engineering

Modeling Engineering Products

Assignment #2

Scaffolding Parametric Model

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Declaration of Authorship

I declare that all material in this submission is my own work except where there is clear acknowledgement and appropriate reference to the work of others.

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1. Design challenge, performance criteria and parameters

The engineering system chosen is a modular scaffolding system[1] with fixed column heights (3m), girder length (3.5m) and ledger width (1.5m) with adjustable platform heights at fixed 0.5m intervals. The placement of these platform heights is based on the needs of the user for working at height.

The **design challenge** was to conceive a user interface which offered flexibility of input for the planner, respecting the fixed modular nature of the system, while providing performance information relevant for ensuring safety and legal compliance.

The **performance criteria** selected were:

- Compliance with legal / safety requirements (embodied in the 'status warnings' dialogue).
- Centre of gravity as a percentage of overall height, again it represents a metric of structural safety, comparative between design options (ie. the lower the centre of gravity, the more structurally secure the system).

Total weight and platform surface area were also provided as metrics to the user, but due to the nature of the system, which directly follows user inputs in a fixed modular way, both the resulting weight and surface area directly correlate to inputs. They report information rather than comparative performance indicators between design options.

The **parameters** to be adjusted by the user are;

- scaffolding length (as a slider in 3.5m intervals from 1 to 10 modules in length)
- list of platform heights (input by the user in a free text box as a list[])

As described above, the design challenge was to implement a usable tool for a construction planner. Thus, *balancing between* parameters which affected the geometry was not so relevant. Rather it was an exercise in balancing usability of the tool. It was important to understand the domain and constraints of the system to strike a balance between;

- flexibility to input multiple platform levels at the discretion of the user, but constrained in terms of strictly not being able to exceed certain thresholds (such as maximum height and fixed platform intervals).
- flexibility to allow the user to override legal requirements (such as head clearance and clear heights) while providing good design/safety prompts. This reflects an understanding of the domain in that the system may, in certain cases, need to be used in an unconventional way. This is understandable as a characteristic of the domain and construction sector more generally, and should be allowed for.

[1] For a full description of the system, please refer to *Assignment #1 - Scaffolding ontology*

2. Logic of the parametric model

The Dynamo graph is grouped into logical sections and colour coded according to a legend adjacent to the user interface. This makes comprehension of the graphs relatively simple for the user, who is further assisted in following the logic with the inclusion of guidance notes and explanatory headers throughout.

Fig. 1 - a colour coded legend assists the user in understanding the graphs logic

The logic reflects an understanding of the construction planning domain. The main objective of the user is to specify heights at which platforms are required based on the object / task at hand. This necessitates a *free text* space (encapsulated in the graph as a list[ ]) as the user may need between 1 and *n* platforms, hence a slider for example would not be suitable. The second input is the length of the platforms. As described above, this is input by the user through a slider in modular increments up to a maxim length. All other geometry in the model is driven by these two inputs only.

Fig. 2 - user interface, all other aspects of the graph are driven by these two parameters

In very simple terms, the logic of the entire graph is as follows:

- User inputs (displayed above) drive the creation of points to modular dimensions using several *Range* nodes.
- These points drive column geometry in modular intervals
- Platforms are composed of girders and deck geometry driven by shapes at points along the centres of curves at level 0 in the *Z vector*. This seed group is arrayed with a *Geometry.Translate* node based on the user input list[] of heights.
- The height of the overall scaffolding is in turn driven by a List.MaximumItem of this same user input list.
- A series of conditional statements are encoded to ensure that safety constraints are met, which in turn result in either disallowing (or *breaking*) the geometry, or by providing status warnings and recommendations, displayed in the user interface.
- Finally, calculations are performed based on the geometry resulting in measurements data and performance metrics being provided to the user interface.

3. Discussing the design space

As discussed previously, there inherently exist rigid constraints in this parametric model. From the fixed modular nature of the system as a whole, to the specific sectional profiles of tubes, girders and decks, and similarly to the fixed incremental heights which must be selected. In this way, it would seem that little variation is possible in design, however, this is not so. The model reflects the reality of scaffolding systems in adhering to a minimal number of interchangeable components, allowing the planner freedom instead in terms of vertical spacing of platforms, as well as an ability to affix further modules above or adjacently. For this reason, variation in the final dimensions of the system could be considered, in fact (or at least in theory!), to be infinite. However, limitations in terms of safe overall height and practical overall length are encoded to provide a minimum (1 x 1) and maximum (10 x 10) design space.

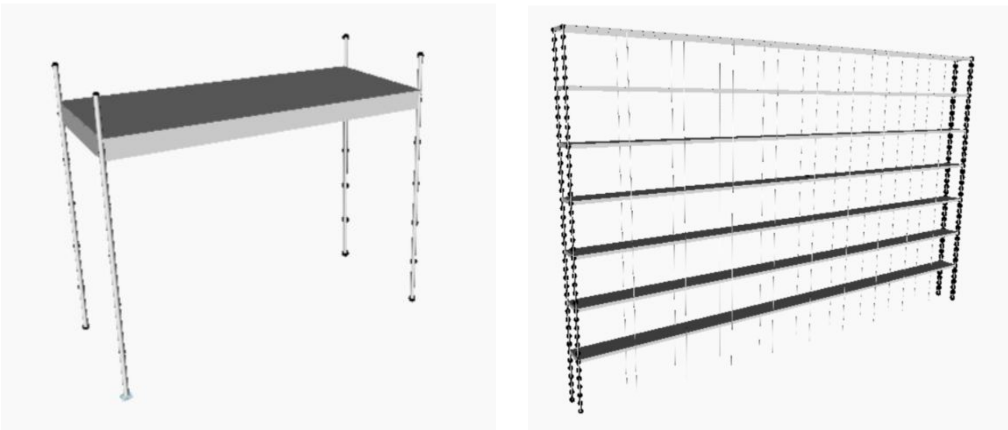

Fig. 3 - the modular minimum and maximum dimensions for the overall system

It is important to mention the conditional constraints encoded into the model. These reflect legal and physical limitations such as a requirement for minimum (2m) head clearance and advising on the need for additional bracing if a specific clear height (>3.5m) is input, unbridged by platforms which perform a stabilising function (providing shear reinforcement). As discussed throughout this report, a main design space for the user is in the specification of platforms. Here the designer has much freedom and can even override legal constraints, accounting for the occasional requirement for unconventional layouts (as discussed in section 1). However, warnings are provided to highlight such breaches. In this way, the model encourages best practice without inhibiting creative freedom and respecting the realities of construction activities.

A limitation of this model is that, in reality, it should be possible to adjust platform heights between adjacent sections. In other words, platforms need not be at the same level along the length of the system. Encoding this functionality would be a completely different engineering challenge. Another limitation of the model is that it does not encapsulate flexibility to adjust for local variation in ground level at individual columns (as discussed in the *Scaffolding Ontology* and personified in the ‘screw-jack’ footing component). This functionality was attempted using the *Point.Project* node, but was later abandoned, another design challenge perhaps to be tackled at a later date.

4. Discussing design alternatives

Three compliant (ie. meeting all legal / physical constraints of the model) alternatives are described below which demonstrates the application and flexibility of the system to adapt to various scales and building typologies.

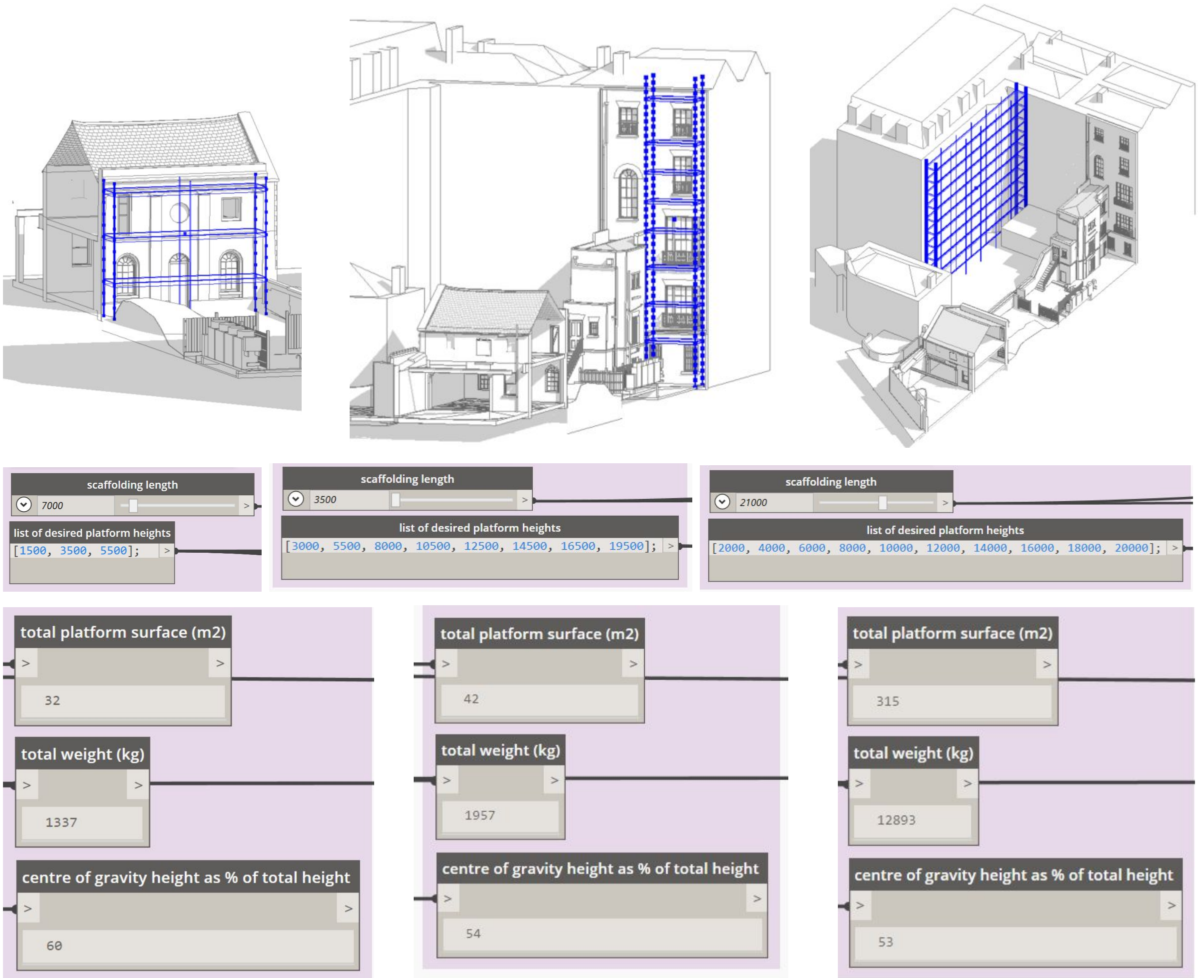

Fig. 4 - three design alternatives which demonstrate the flexibility of the parametric model

In all three options, the centre of gravity being between 50-60% of total height means that the weight is quite evenly distributed up the frame. If the height of centre of gravity were, for example, to be reported as 80-90% up the frame, it would raise serious concern as to the stability of the design. This, while not impossible (remember, the planner may override several of the legal constraints), would be flagged in the status warnings to the user as it would certainly mean significant clear spans without platforms at the lower levels.

The flexibility of the system is demonstrated in the three examples in that the 0.5m platform increments work well in a repetitive case (example 3 of a modern building) as well as in non-evenly distributed cases (examples 1 & 2, typical Georgian era window distribution). In all examples it can be seen that the planner has full flexibility to add to the platform list and easily adjust the length with the slider, these the only 2 inputs required to set out a full scaffolding system with this simple to use tool.