VISUALISING THE RELATIONSHIPS BETWEEN DESIGN OPTIONS & REGULATORY REQUIREMENTS

Visualizing Regulatory Design Solutions

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Abstract. To maintain high quality environments, the Australian government provides standards such as the Building Code of Australia (BCA) and Australian standards, that outlines the minimum requirements for safety, health, amenity and sustainability in the design and construction of new developments. Considering the vast number of situations possible, the BCA and AS are lengthy documents, and consequently understanding these regulations can be an arduous and time-consuming task for architects. Furthermore, misunderstanding regulatory standards can lead to costly errors associated with remediation in later stages of the design process.

This research asks, how can we spatially visualize and model these standards to better inform design decision making? This question will be addressed by testing how computational design tools can mitigate against errors in interpreting regulations, focusing on creating a workflow/script for visualize the regulatory requirements to allow architects to have a clearer understanding of the BCA standards, and moreover, to model the design outcome that allowable for architects to edit further in order to produce the best outcome.

Keywords. Visualization, Modelling, Regulatory Standards, Data Analysis

1. Introduction: Research Motivations

To maintain high quality and sustainable living environments in 21 century, the Australian government provides regulatory standards such as the Building Code of Australia (BCA), the Apartment Design Guide, Development Control Plan and the Local Environment Plan as well as a series of Australian standards. These regulations provide guidelines for minimum and necessary safety, health, amenity and sustainability requirements for the design and construction of new developments. Considering the vast number of situations possible, the BCA and AS are lengthy documents, and consequently understanding these regulations can be an arduous and time-consuming task for architects. Furthermore, misunderstanding regulatory standards can lead to costly errors associated with remediation in later stages of the design process.

While there are a few of tools that assist architects in analyzing or evaluating building performance, such as Solibri and CostX. These tools mainly focus on the sustainability of a development, and apply to buildings all over the world. There are few tools that help architects with simulating and/or visualizing the Australian regulatory standards, in order to more fully understand requirements of a country's specific conditions.

In addition, computational design or architectural computing is a newly developing field of the built environment. Computational design approaches emphasis the use of 3D modeling, computer science and digital fabrication. Cutting edge digital technologies and software are little known or used in traditional architectural practices, resulting in difficulty of developing such tools to assist architects and enhance the design outcome. This also explains why specialized consultants are often needed to help architects understand different standards, thus, suggestions and supervisions from specialized consultants are important, which results in time spent on meetings and extra costs for client.

With cutting edge technologies developing rapidly, such as 3D printing, Interactive technologies are able to assist us in achieving difficult target, which leads back to the research aims, simulating and/or visualizing the regulatory standards in order to assist architects to have a thorough understanding of it.

2. Research Aims

This research project explains how to design a workflow/script for architects to use, to visualize regulatory standards in 3D. As mentioned above, understanding these lengthy documents can be an arduous and time-consuming task for architects, however, the understanding of these requirements can be largely improved through visualization. Because visualization through visual imagery is an effective way to communicate ideas as it improves the understanding for audience. With the same theory, through visualization, architects are able to have a thorough understanding of the requirements such as calculating equations for sizes and moreover, to visualize different outcomes to have a wide range of design options as reference. As the result, the project aims to develop an Australian standards' visualization tool to assists architects to have a better understanding of them. Simulating the standards against a visualizing tool will largely help architects in making design solutions. The workflow is prepared for the early design stage, when architects are designing the structure and details of a project, with visualizing the requirements, it will reduce cost and time through the design process. The algorithmic modeling plug-in, Rhino + Grasshopper has its strength in developing the workflow/script for visualizing the regulatory standards. Thus, it will be the main developing software used throughout the project.

3. Research Questions

" In what ways, can the relationships between design options and regulatory requirements be visualized/spatially modeled to better inform design decision making? "

The difficulty of understanding numbers of regulatory standards leads to the research question. This can also be explained as how can we improve the design outcome further by using tools for assistance, and what are the benefits. As a numbers of analyzing tools have been developed after Building Information Modelling (BIM) got popular in built environment, however, most of them are used in analyzing energy, sustainability or safety issues. There are few tools that assist architects to have a more accurate understanding of requirements of a country's specific conditions. This research explores the relationships between design options and regulatory requirements, and finding ways of how to improve the understanding of these requirements.

4. Methodology

Based on the existing knowledge and understanding of the Australian standard, the Building Code of Australia, the research develops a workflow/script that could inform architects with limited knowledge on the Australian standard of the requirements used in a building through visualization. This research project was developed through an action research method, with a process framework that firstly identify the problem and develop a solution, carrying out the solution, evaluating and reflecting on the solution before creating the new solution (Gabel, 2017).

With the problem of considering the vast number of situations possible, the BCA and AS are lengthy documents, and consequently understanding these regulations can be an arduous and time-consuming task for architects, nonetheless, misunderstanding regulatory standards can also lead to costly errors associated with remediation in later stages of the design process. A script tool will be developed in assisting architects to have a better understanding of the Australian standards.

Through the steps of action research method, the workflow/script will be developed based on a few stages. Firstly, with the plan of developing a workflow/script for analyzing the Australian standards, the visualization is the most important part of this practice, which means the script must be able to responds based on the actions taken. The details of how to achieve that will be elaborate further in later. After this stage, the regulations from the BCA will be transformed into expression components, this allows the visualization responds with the right value according to the Australian standards. By modelling a basic staircase in grasshopper, we are able to visualize the regulations with different values. With evaluating the workflow, it will be developed further and keep repeat the actions until it has been finalized with an accurate and clear presentation.

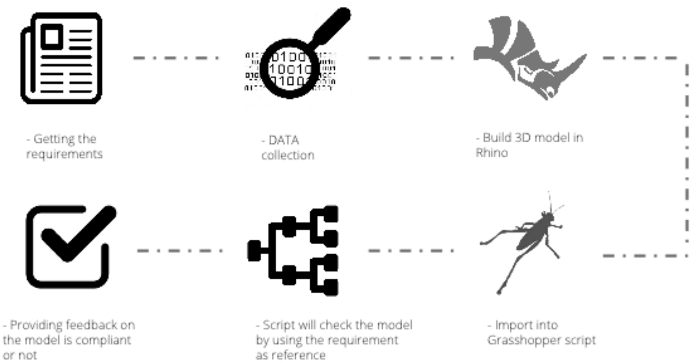


Figure 1. Planned Workflow

In this research, the requirements of a staircase will be used as an experimental object. Within the workflow/script, a general stair model was modelled through grasshopper for architects to optimize before starting the calculations based on the Australian standards. Color voxel grid will be showed on the model surface to highlight the errors according to the calculation results. Showing if the model is compliant with the Australian standards or not.

Furthermore, architects are able to continue optimizing the model in order to test different possibilities until getting the best design solution from the workflow/script.

5. Background Research

The last decade in architectural practice has witnessed a significant shift in our understanding and use of digital tools. The most significant recent development in the field of architecture is the realization that software processes aren't simply tools designed by software developers - they can become the very material from which designs are made (Suleiman Alhadidi, 2016).

5.1. BUILDING COLLABORATION PLATFORMS FOR MULTI ARCHITECTURE BUSINESS

This abstract seeing that Architecture is currently experiencing a paradigm shift in the process and conceptualisation of design and professional practice. Apart from designing a concept, architects are shifting to a role of providing a design solution.

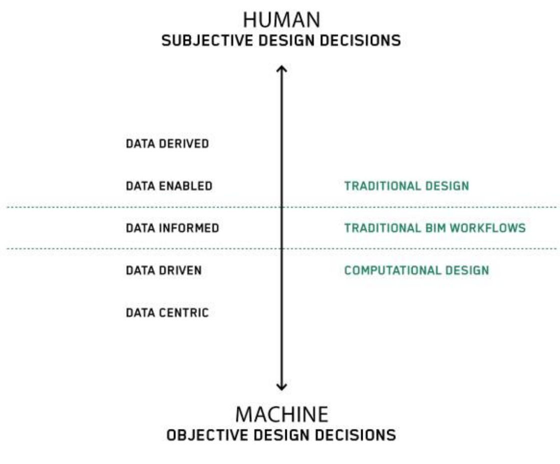


Figure 2. Type of DATA verses Design methodology

This is caused by the rapidly development of smart technologies. However, this change will not deny the role of the architect, nor devalue traditional praxis. It offers a new modes of multi-disciplinary and collaborative practice formed on performance based computational framework which available in receiving rapid feedback and testing of design.

5.1.1. Design with DATA: Information/Data Driven Design

With new cutting edge technology, such as the Internet of Things (IoT), a network of devices that used for data collection and data exchanging, are providing new opportunities for the architecture, engineering and construction industries. Within the contemporary practice, designs have been using data to inform the design process. One example of such processes is the use of weather data to assist in compliance with solar access requirements for residential design. Within the state of NSW in Australia, section 4A of the State Environmental Planning Policy No.65 (SEPP65, 2015) sets out design guidelines, objectives and criteria for solar and daylight access within residential apartment developments. By utilizing the local weather data, designers are able use data-enabled parametric design processes to set solar access values and parameters to modify building orientation, building fenestration and design solar shading devices so as to comply with SEPP 65 guidelines.

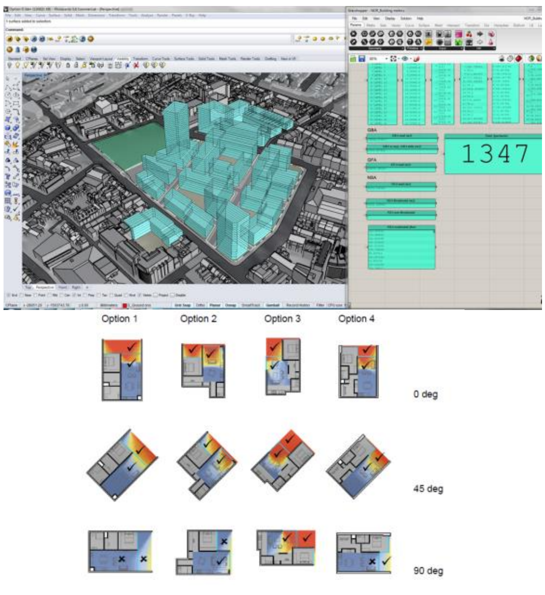


Figure 3. SEPP65 Residential development script which account for code requirements

5.2. THE BUILDING CODE OF AUSTRALIA

The National Construction Code (NCC) is an initiative of the council of Australian government, developed to incorporating all on-site construction requirements into a single code. The Building Code of Australia is Volume One and Volume Two of the NCC report, which focusing on the building behavior.

5.2.1. Staircase

The stairway must be designed to take loading forces in accordance with AS/NZS 1170.1 and must have not more than 18 and less than 2 risers in each flight. This is because for place where there are less than 2 risers in a flight, it does not comprise a stairway for the purpose of the BCA. On the other hand, 18 risers is considered to be the maximum reasonable number that an average person can negotiate before requiring a rest.

Table 3.9.1.1 RISER AND GOING DIMENSIONS (mm)

STAIR TYPE	RISER (R) (see Figure below)		GOING (G) (see Figure below)		SLOPE RELATIONSHIP (2R+G)	
	Max	Min	Max	Min	Max	Min
Stairs (other than spiral)	190	115	355	240	700	550
Spiral	220	140	370	210	680	590

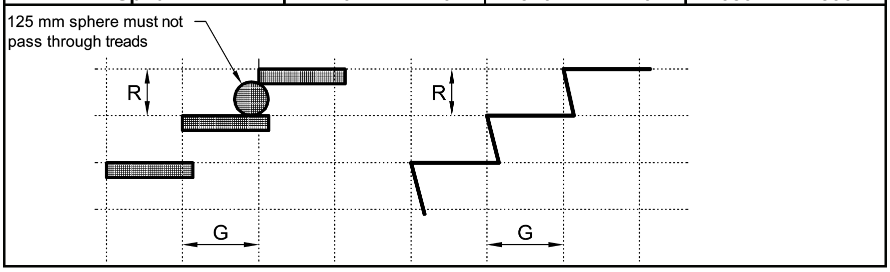


Table 3.9.1.1. Riser and Going Dimensions

The stair also must be compliant with the table prepared by the government, showing the goings as G, riser (R), and the relationship quantity with an equation 2R + G. This is to achieve constant going and riser dimensions deemed safe for people to walk up and down. This minimises the risk of people overstepping during descent on uneven stairs due to short goings and tripping on ascent which due to high risers. The ratio between going and riser showing on the Table 3.9.1.1 are used in considering safety for use.

Table 3.9.1.2 RISER AND GOING DIMENSIONS (mm) — STAIRWAYS SERVING NON-HABITABLE ROOMS USED INFREQUENTLY

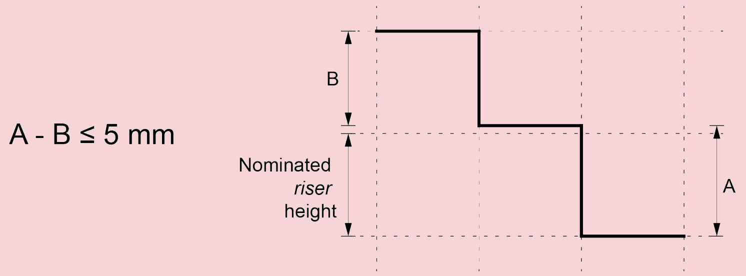
RISER (R)		GOING (G)		SLOPE RELATIONSHIP (2R+G)	
Max	Min	Max	Min	Max	Min
225	130	355	215	700	540
Note: The *going* (G) shall be not more than the tread depth plus a maximum gap of 30 mm between the rear edge of one tread and the nosing of the tread above.					

Table 3.9.1.2. Riser and Going Dimensions for Non-Habitable rooms

For staircase that is used in serving Non-habitable room, such as attics, storerooms, and the like are provided with a different standard.

MINOR DEVIATIONS IN A STAIRWAY

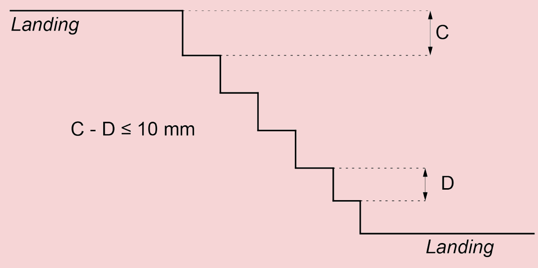
Diagram a. **Deviation in adjacent risers**



Notes:

1. A = larger *riser* of two adjacent *risers*.
2. B = smaller *riser* of two adjacent *risers*.
3. This diagram only shows deviations in *risers*, however the same principle can apply for *goings*.

Diagram b. **Deviations over a flight**



Notes:

1. C = largest *riser* of the *flight*.

Figure 4. Minor Deviations in a Stairway

Diagram a illustrates adjacent risers within a flight with minor deviations in the materials affecting the finished stair dimensions. The nominated riser height is exceeded by riser A. As a consequence riser height B is less than the nominated riser height. The difference between riser A and riser B cannot exceed 5 mm.

Diagram b illustrates an entire flight with minor deviations in the materials affecting the finished riser dimensions. In addition to the 5 mm difference permitted between adjacent goings or risers, the maximum difference between the smallest and largest going or riser within a flight must not exceed 10 mm.

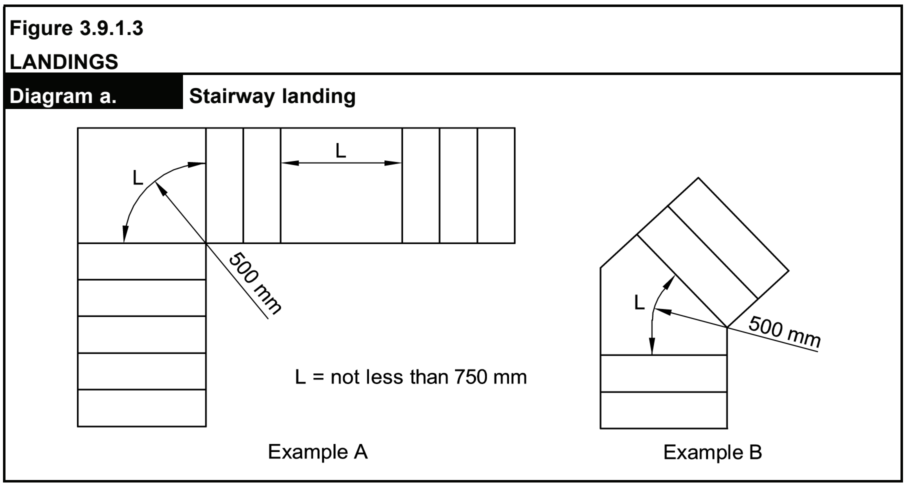


Figure 3.9.1.3. Landings Diagram a

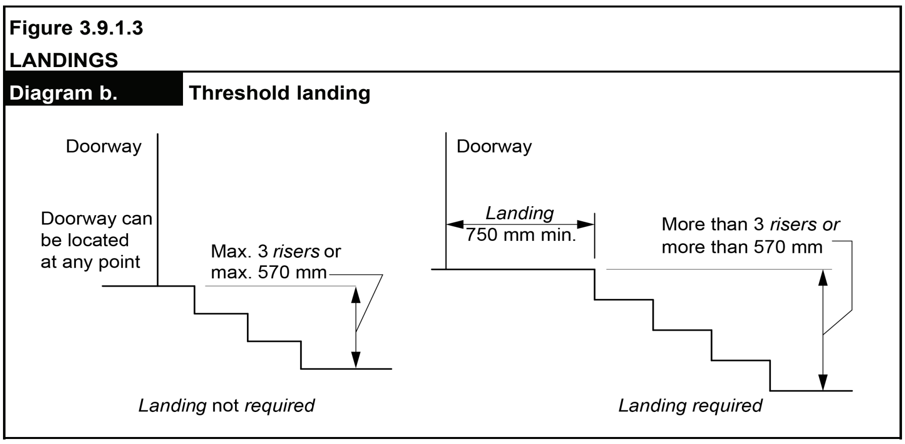


Figure 3.9.1.3. Landings Diagram b

Landing must be used if the stairway has more than 18 risers, it must not less than 750mm long and where this involves a change in direction, the length is measured 500mm from the inside edge of the landing and have a gradient not steeper than 1:50, the landing also must be provided where the sill of a threshold of a doorway opens onto a stairway or ramp that provides a change in floor level or floor to ground level greater than 3 risers or 570 mm, and extend across the full width of a doorway. The purpose of a landing is to provide a rest area for people using the stairway or ramp, and to allow the stairway or ramp to change direction if needed. The minimum length of the landing allows people while using the stairway or ramp to rest, reduces the risk of people falling more than one flight of stairs. The 1:50 gradient for the slope is used to make sure that the landing is as level as possible, but still allows a slight slope for drainage if necessary.

6. Case Study

Rhino, Grasshopper. The algorithmic modeling plug-in, has its strength in developing the workflow/script for visualizing the regulatory standards. Thus, it will be the main developing software used throughout the project. Based on the understanding and data collection of the Building Code of Australia, the workflow/script will only use the regulation of a staircase as an experimental subject.

Figure 5. Rhinoceros and Grasshopper plug-in logo

The workflow/script will mainly focusing on the Width of the staircase, Number of risers, Depth of the riser, and the Height of the riser. In the workflow, a basic staircase was modeled in Rhino Grasshopper, this is a general stair model that applies to a common situation, within the workflow/script, a series of number sliders are provided for adjusting the stair model on sizes such as the height of the level, the number of steps, the stair width and the depth of each riser. Architects are available to insert their expected values before the script start calculating the errors by using the equations provided from the Building Code of Australia.

Table 3.9.1.1 RISER AND GOING DIMENSIONS (mm)

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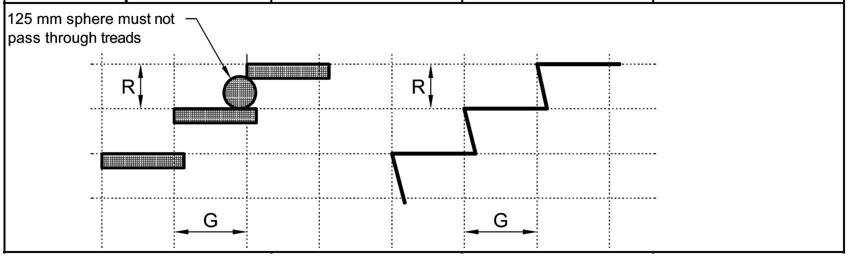

Table 3.9.1.1. Riser and Going Dimensions

Based on the background research at early stage, the requirements and/or equations have been highlighted on the BCA. These requirements and/or equations can be calculated or transformed into an expression component, if… then… As the expression component can be used to solve mathematical algorithms and return numeric data as the output, it is a easy way of allowing the script to generate a range of value, if the input value is within this range, the calculation will continue, if the input value is out of this range, it will produce another series of calculation which both of them leads to the visual feedback at the end.

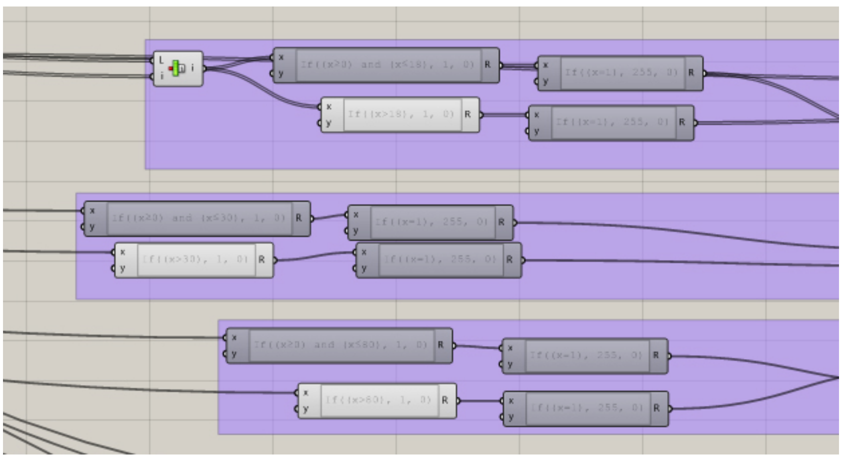

Figure 6. Expression component in Grasshopper

Another way of importing DATA is to creating an import plug-in, which is used for architects to import the requirements by themselves. This is helpful in using the latest version of the Australian standards, as the government will update the Australian standards regularly, small changes may cost huge different, therefore, always referring to the latest requirements is important to the user.

Base on the values insert by architects, the expression component will evaluate the numbers and produce true or false result through the outcome, by connecting the outcome with a color optimizing component, the tool will generate visualizations to the model according to the result. To make the calculation results understandable and easier for architects to differentiate errors, the visualizations of the workflow/script will use colors to highlight and differentiate places where is compliant or failure. This could be helpful as in providing part that goes wrong to makes easier for architects to concentrate in solving the issues with that particular area instead of redesign the whole structure again. Further, the number sliders also help architects in adjusting the model, testing numbers of combinations to understand the tricks of the requirements, eventually, finalize the best design solution that is suitable in their circumstance.

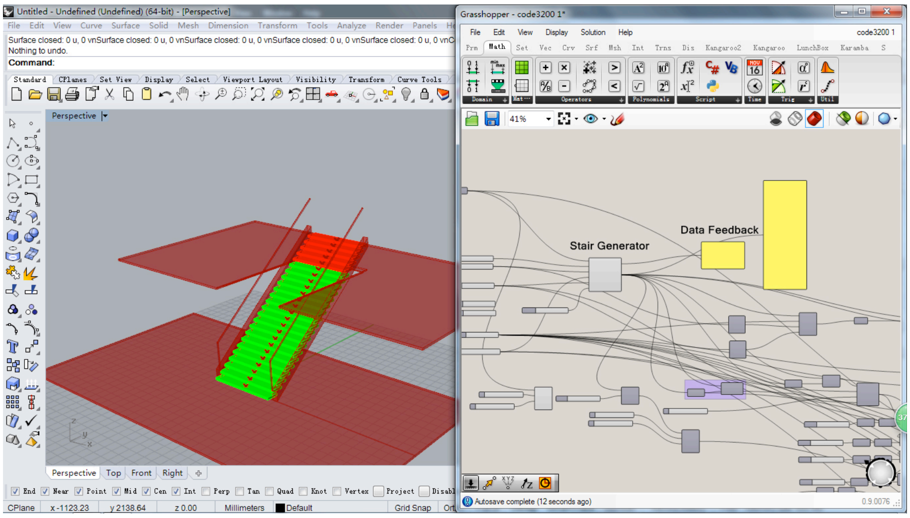

Figure 7. Visualization of stairs over 18 risers

Considering of different situation, a few types of staircase have been modeled within the workflow in order to apply to majority of the circumstance. For example, if the workflow/script recognized that there is a landing in between risers, which with a purpose of allowing people to have a rest, according to the Australian standards, the calculations for 18 risers will be refreshed, which means the counting will be start over until the number of riser is up to 18 again. This is highlighted on Figure 8, which is showing that although the total number of riser is over 18, however, due to the landing set after 9th riser, the calculation of the riser continues. Therefore, the workflow is showing compliant based on the situation.

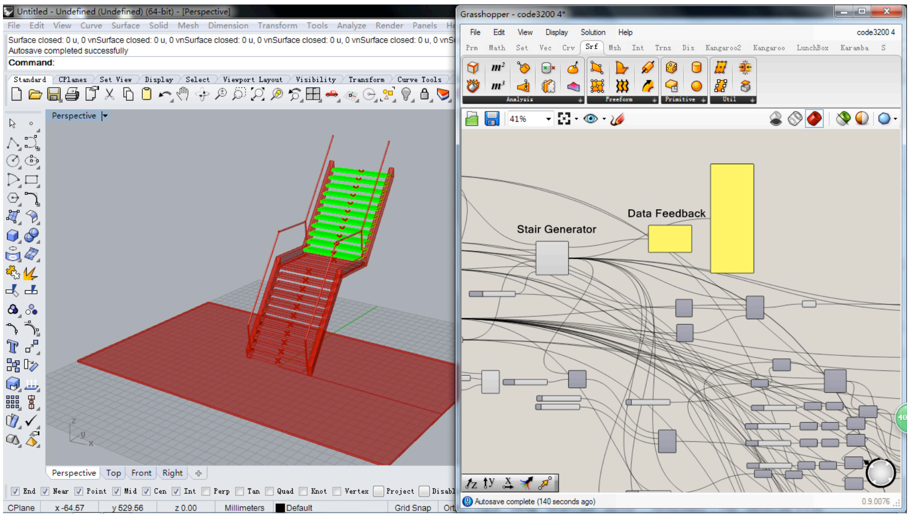

Figure 8. Visualizing stair with landing

Round stair also applies to the workflow/script, it is success on showing the number of risers, the height of riser as well as the width of the staircase. Including round stair into the workflow ensures the tool covers majority of the circumstance, extend the possibilities of designing different concept of stairs. This could be developed further in order to apply to all the situations.

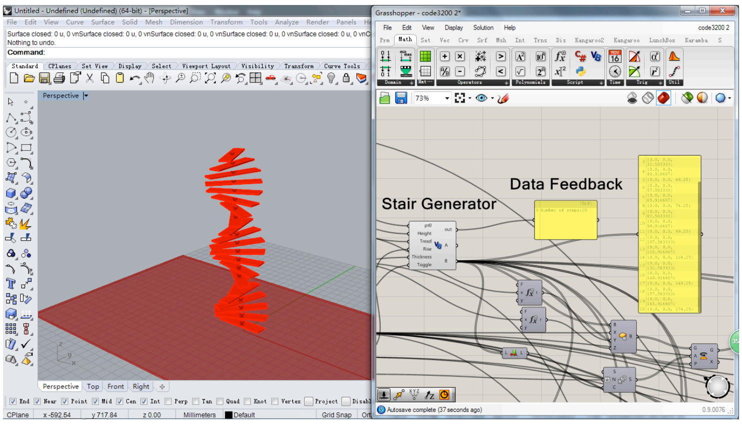

Figure 9. Visualization of Round stairs (not compliant with width)

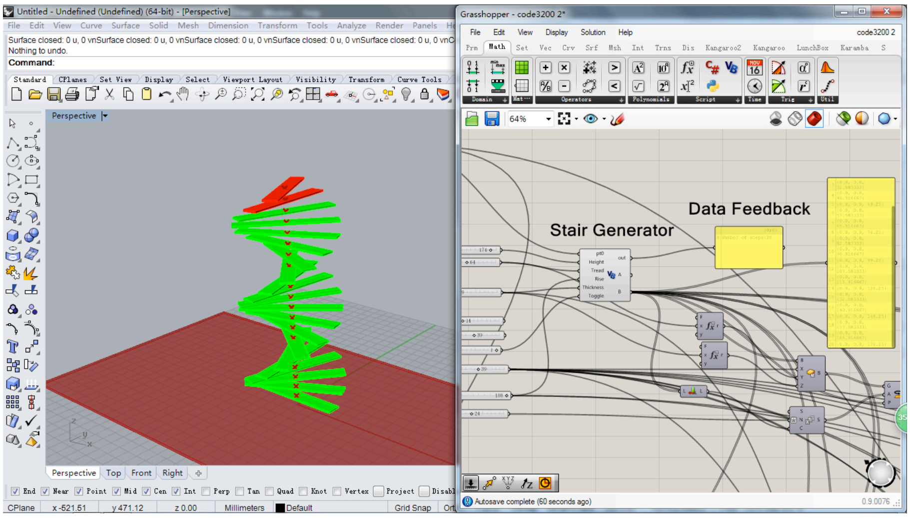

Figure 10. Visualization of Round stairs over 18 risers

In the development of the workflow/script, it is successful in visualizing feedbacks on a number of basic stair models, the calculations are accurate according to the formula given in the Australian standards. However, by manually making the stair model more complex and more errors produced, the script is unable to identify and visualizing for more than one errors. This might because of the numbers of expressions developed in the script, more errors found makes the calculations harder in comparing with only one error was made. It could be fixed by re-structuring the script, divide the expressions into different steps, also can be explained as a linear calculation workflow, instead of a branch type of structure. Nonetheless, due to yearly update by the government, the standards are changing regularly, this could be an issue when the latest of standards released, however, the workflow are still using the old version. It may cost a very serious consequence due to using the old regulatory requirements.

7. Significance of Research

This research explores and highlights the importance of using computational technologies to assist architects and builders to have a better understanding of the Australian Standards. As the abstract mentioned above, the architecture industry is currently experiencing a paradigm shift in the process and conceptualisation of design and professional practice. Apart from designing a concept, architects are shifting to a role of providing a design solution. Under traditional architecture, the development is slowly forward to realizing that software processes are not simply tools designed by software developer, they have a lot of potential on becoming the very material from which designs are made. With these cutting edge technologies developing rapidly, such as Internet of Things (IoT), 3D printing and Interactive technologies are very good resources to assist us in achieving difficult target throughout the development. Apart from other analysis tools, this research is focusing on analyzing the Australian Standards, which is provided by the Australia government with the purpose of maintaining high quality and sustainable living environments. With this concept, it could largely reduce the time and cost through a design process, nonetheless, minimizing errors that could be produced during early design stage. Through a better understanding of different Australian Standards provided by the government, the assisting tool will produce a more accurate, more dynamic and more suitable design solution based on different circumstance. This leads to developing a strict quality of living environment based on the Australian standards. Enlarging the possibilities of every circumstance, and architects are able to widely choose among the possibilities in order to produce the best outcome for client.

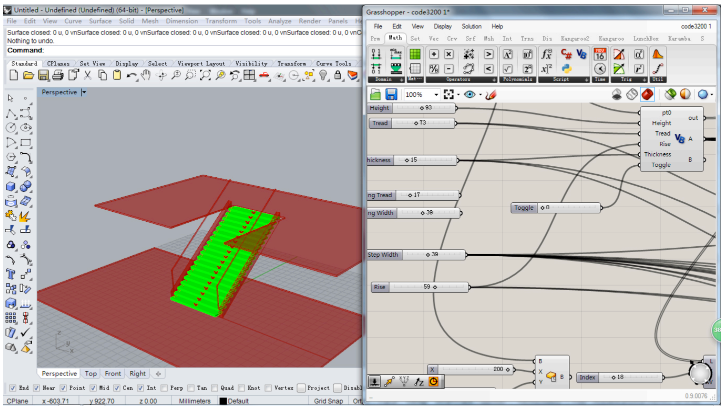

Figure 11. Visualizing a compliant staircase

8. Evaluation of research project

Base on the experiment and the results of the research, the next step is recommended on finalizing the workflow/script to upgrade its performance as in adopting with more complex stair models as well as more standards regarding different type of stairs. This is to make sure the tool is able to provide a wide range of design options and/or design solutions, nonetheless, apply to every circumstance allows architects to have numbers of concept, this enlarge the possibilities of design, encourage architects to develop more dynamic and frontier buildings. Also, as mentioned above, the structure of the script can be re-organized to achieve a better visual performance. Creating a import port for architects to import the equations and requirements straightway before analyzing, this can be a method of solving the issue of government's regular updates on the Australian standards, and/or with future development, this workflow/script can be co-operating with the government, such as a self-updating database which updates yearly according to the government. This ensures the tool is always following the latest requirements to work perfectly accurate in calculation. Developing this workflow/script will largely helps architects in having a better and deeper understanding about the Australian Standards through visualization, and assists architects to carry out a better design solution at the early design stage after a series of tests within the tool. Furthermore, the success of visualizing the staircase could leads to visualizing other fields of the Australian Standards by using the same theory. Such as standards for bathroom, disable access, parking, ramp and so on. This could largely improve architects' understanding of the Australian Standards and assists communication between consultants and architects, to create safer, dynamic, aesthetic design solutions. As mentioned earlier, the Architecture is currently experiencing a paradigm shift, architects are shifting from designing a concept to a role of providing a design solution. Such tool will be a verification of this fact, allowing architects to verify their solutions against problems.

9. Conclusion

This research project explores how computational design tools can mitigate against errors in interpreting regulations and assist architects to better understand them. By using staircase as the experimental object, a workflow/script was developed to visualize the Australian standards and providing feedbacks for users to have a clear understanding of it. In this research, the regulations of the staircase from the building code of Australia has been studied, it helps in improving the quality of the experiment practice in later stage.

A workflow/script has been developed according to the standards and calculations from the Building Code of Australia. Through the action research method, a series of evaluation and improvement have been made. By using algorithmic modeling software, the Rhino + Grasshopper plug-in, it is successful in visualizing the Australian standards by providing visual feedbacks based on the values that architects insert to the experiment model. It gives a clear expression on what is a compliant staircase model looks like and how to achieve it. Different from other analyzing tools such as Solibri and CostX, these tools are using in evaluating or analyzing the building performance before construction. However, the proposed tool is only focusing on analyzing the Australian standards that are provided from the government, it helps in evaluating the proposed design with the relative requirements, it will minimise the cost and time throughout the design process.

In addition, with developing such tool, this research has achieved the purpose of building a bridge between computational design and traditional architecture, as computational design approaches emphasis the use of 3D modeling, computer science, digital fabrication and other cutting edge digital technologies, these technologies and software can be developed further in assisting traditional architecture.

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