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Bridging the Gap between Design and Simulation based on validated Daylighting simulation and Parametric modelling tools

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Abstract

The author propose a new way for optimizing the building performance while taking the advantage of using the parametric environment that allows different modifications happened without the need of regenerating the entire model every time. Furthermore, it will make designers uses a daylight validated tool -Radiance- inside their computational tools -Grasshopper- while preserving a user friendly interface.
The expected result will be an algorithm which automatically affects the parametric design based on the feedback of daylight performance. As a result the algorithm will generate and evaluate all different possible configurations within the predefined limits of each parameter, and present the most optimized set of solutions.
The author will evaluate the daylight performance of one building. Then, the new optimization algorithm will be run over the building parameters. The daylight performance of new generated design variations will be evaluated. Finally a comparison between the old and the new optimized solution will be discussed.

Keywords: Parametric, Optimization, Daylight, Grasshopper, Radiance.

1 Introduction

The idea of bridging the gap between design and environmental simulation has been discussed over the last few years. Each time the discussion ends with a recommendation that it would be useful if a new tool could engage the simulation results in the early phase of the design development, but until now no commercial tool is available to public because most of the computer aided for drawing companies are focusing on developing the modelling capabilities of their software packages rather than searching for new ways to get a full integration with validated simulation tools (Wagdy, 2012).

The parametric modelling tools rise as new revolution to the computational community, these tools such as Grasshopper by McNeel & Associates, Bentley Generative Components (GC) and more recently DesignScript by Autodesk (Harding et al, 2012) have more advantages than the typical cad tools, because it can manipulate a complex set of modelling information date at the same time without any need of regenerating the 3D modelling information each time (Wagdy, 2012).

The author proposes a new approach to integrate the simulation results with design creations in order to achieve the best performance design. In this sense the new logic is based on optimising the daylight performing a closed loop process which will allow the parametric design to be modified by time until it reach the best possible daylight simulation inside the space.

2. Objective

This research aims to enhance the daylighting quality of gymnastics space based on optimizing shape of wall section of the building. The author will use the new tool that he developed because it contains all the features that should be included to have a simulation driven design.

The key features of the new tool are:

- Improves the quality of architecture design based on Daylight simulation.
- Closes the gap between design and simulation software.
- Generate different design solutions, quickly.
- Searches in automatically process for the best possible daylight solution.
- Can solve the problem of uneven distribution of daylight.
- Provides different daylight solution depending on different space functions.

2.1 Methodology of Parametric Workflow

This paper shows a new parametric workflow which runs in automatic mode without the need to export or import the 3D modeling information between each type of software to have totally automatic optimization process. This new effective workflow is done inside Grasshopper as shown in Figure **1** , it allows the user to work simultaneously with one platform which has the ability to export the 3D modeling information, material properties, and analysis grids into Radiance/Daysim format and calculates a series of daylight illumination analyses. After that the simulation are automatically loaded back into the Grasshopper with the numeric values of each the analysis points as well as RGB color mappings. In that case the analysis results are evaluated within fitness functions, giving feedback which is processed in a loop action inside the evolutionary solver. This optimizes the algorithm parameters through time to find the best configuration that allows better daylight illumination (Wagdy, 2013).

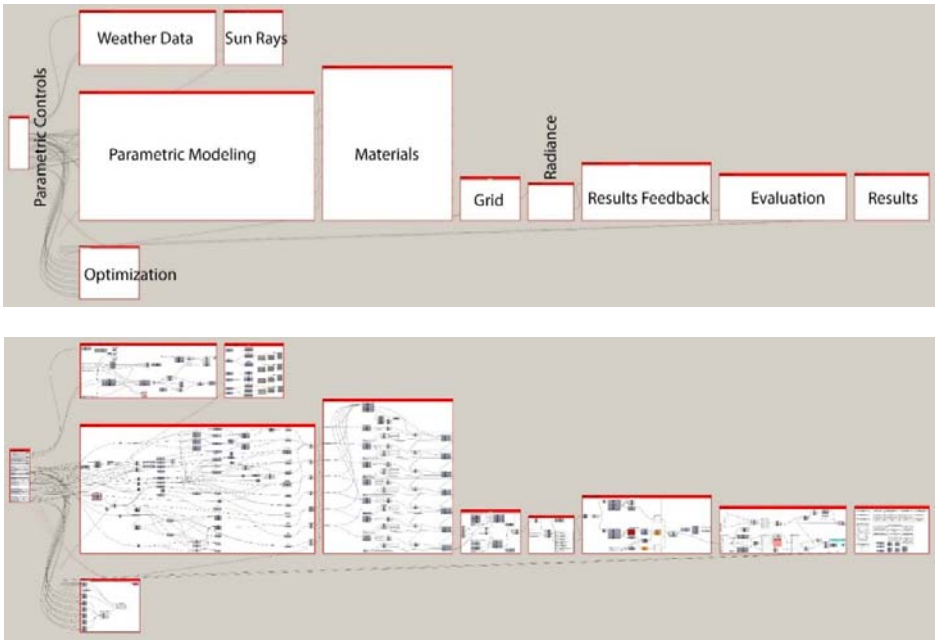


Figure 1. Shows the main logic scheme and the Grasshopper definition.

3. Case study

In Nieuw Welgelegen (TNW), Netherlands the case study is located. It is a sports hall dedicated only to gymnastics. It is a part of a sports complex in the centre of Utrecht in the Netherlands. The case study is a building by TATA Steel, called “The Tulip”. The building is formed by sweeping a double curve wall profile over a rectangular perimeter, and the transparent part is surrounding the flat roof around Shown in Figure **2**. Which allows the natural light entering the space indirectly because it uses the perimeter walls as reflectors (Davis, 2012).

Figure 2. Exterior and Interior shots of the building.

3.1. Problem of case study

The main problem with daylighting inside this space is the present of direct sunlight shown in **Figure 3**. It causes glow and very high luminance ratio, the problem become very clear after evaluating the daylight of the current design solution.

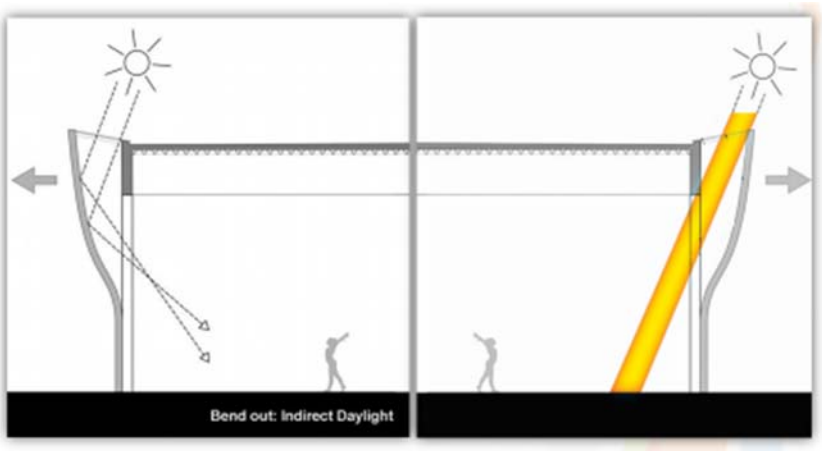


Figure 3. Shows the direct access of the sunlight.

3.2. Daylight evaluation of current design state.

The simulation results in Figure **4** show the minimum illuminations value equal to 97 Lux and the maximum illuminations value equal to 46283Lux. These values are extreme in comparison with the recommend daylight illuminations values by IESNA (IESNA, 2000). For sports hall the required daylight illumination is equal to 500Lux as minimum and 2000Lux as a maximum.

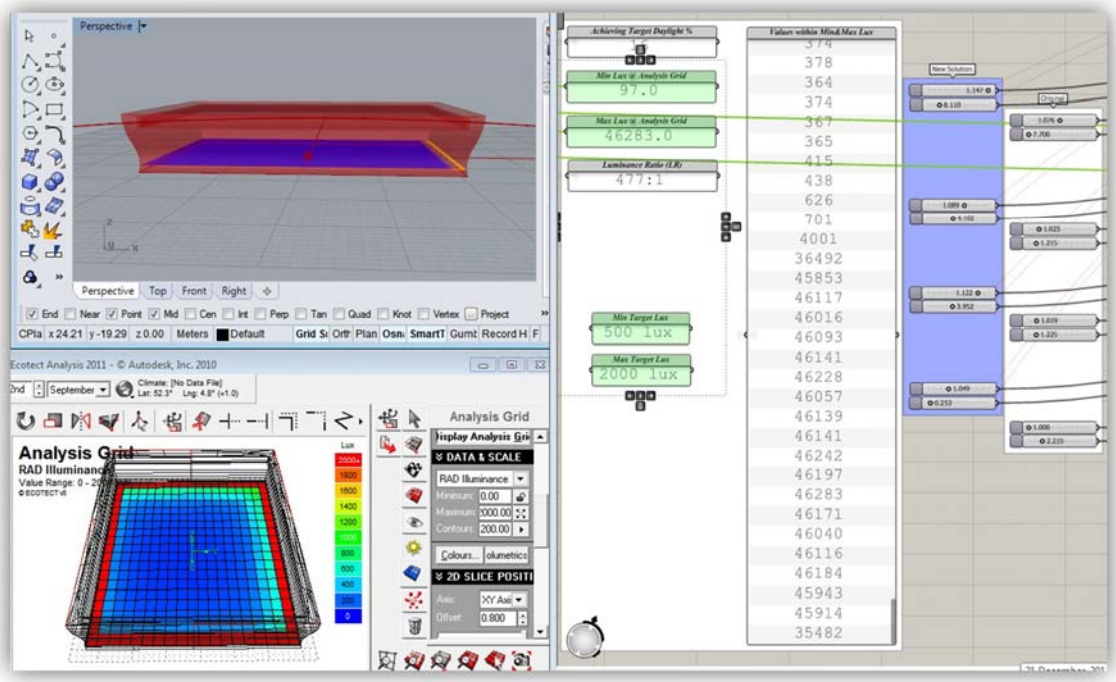
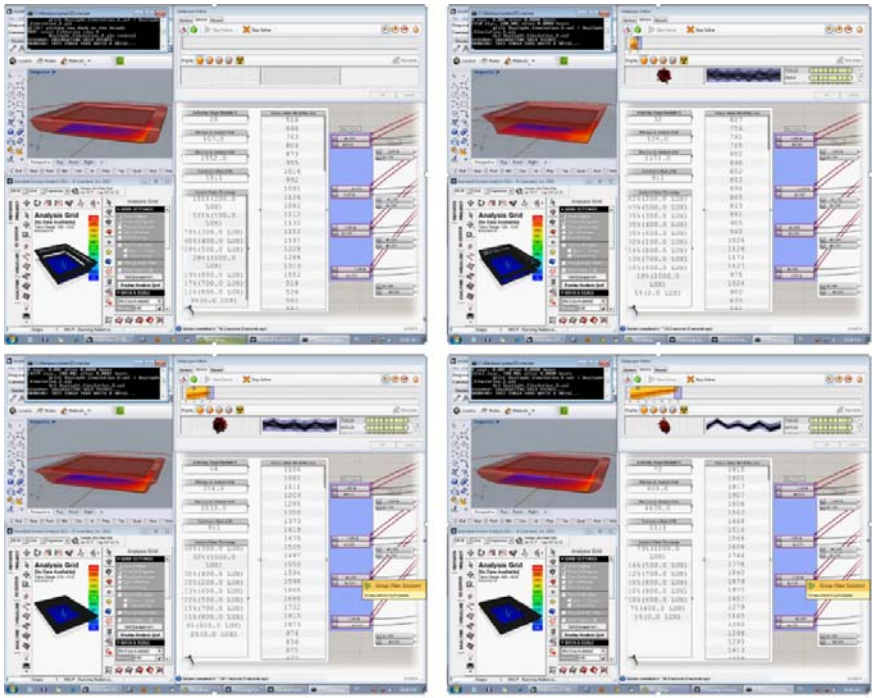


Figure 4. Shows the daylight evaluation of current design state.

3.3. Optimizing process.

The process shown in **Figure 5** is developed by linking the daylight simulation results with each design generated. This integrated design/performance feedback loop controls the parametric design parameters in fully automatic process. The optimizing engine is based on genetic algorithm that has the ability to reduce the range of acceptable design variables through time.



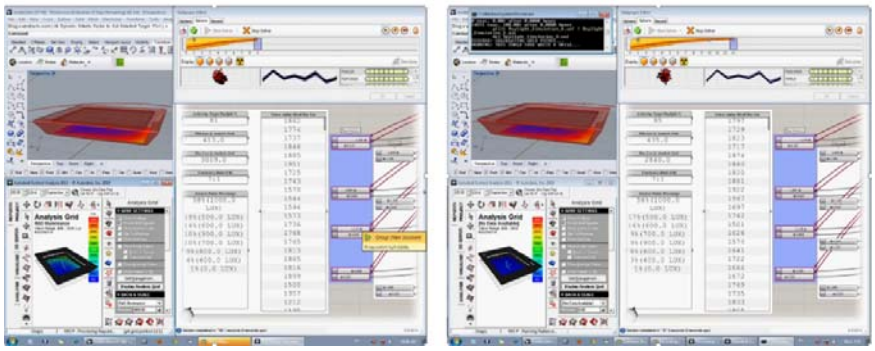


Figure 5. Shows the optimization process based on the daylight simulation.

3.4. Daylight evaluation of the new optimized design state.

After the optimization process is finished shown in Figure **6**. The new wall shape which generated based on the daylighting simulation distribute the daylight much better than the original design and prevents the direct sunlight from entering the space.
The new simulation result shows the minimum illuminations value equal to 448 Lux and the maximum illuminations value equal to 2784Lux. The luminance ration equal to 1:6 which is considered better than standard luminance ration which is equal to 1:10 (IESNA, 2000).

As it shown in the same Figure **6**. Some design parameter stopped on the limits – the first and the last metric sliders- indicate that those parameter limits needs to be increase in order to reach 100 % of the daylighting performance objective.

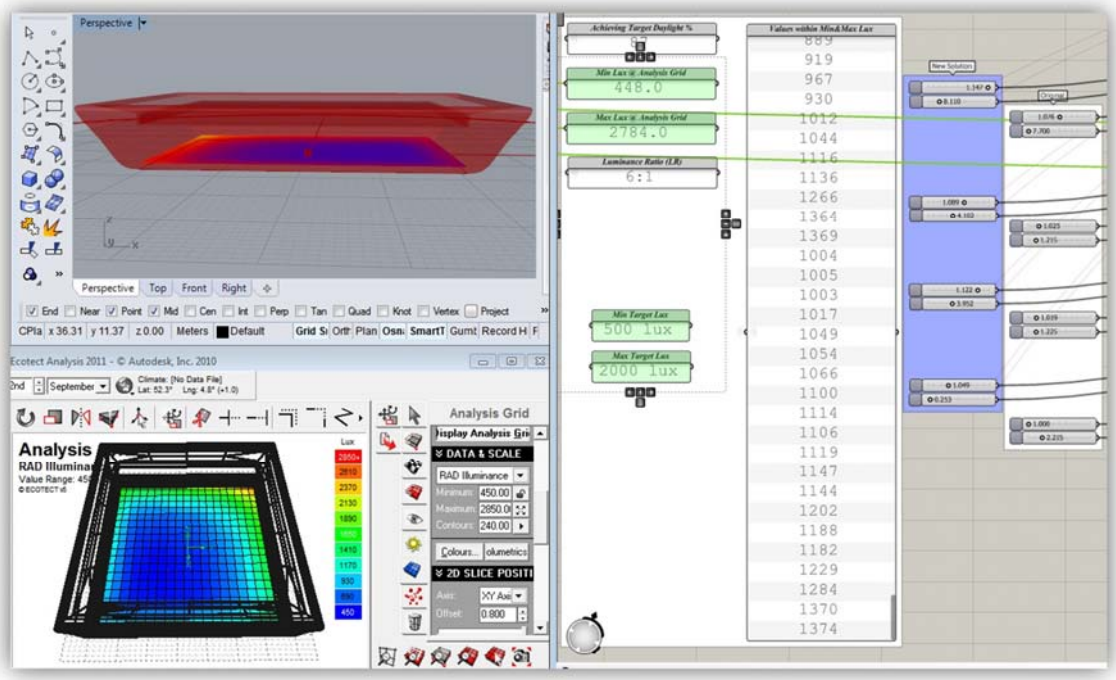


Figure 6. Shows the daylight evaluation of the new optimized design state.

4. Conclusion

As a conclusion, this new workflow revels the real benefits of using daylight analysis in architecture design. It uses the analysis data and evaluates it, then it changes the design parameter to achieve better analysis results in the next evaluation. This loop process of enhancing the design runs automatically until it reached the best possible solution within the predefined design limits.

This new tool offers a new ways for design exploration and evaluations in totally interactive process. And it allows for many design variations to be evaluated against different daylight solutions with artificial intelligence algorithm which search for the best possible solution through time. Ultimately, this workflow could be upgraded In the future to involve different environmental factor such as (solar radiation, wind and ventilation, energy demand, thermal losses and more), by involving it with other validated simulation tools.

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