Façade Components Optimization of Naturally Ventilated Building in Tropical Climates through Generative Processes. Case study: Sumatera Institute of Technology (ITERA), Lampung, Indonesia

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Abstract Global warming and climate change have led to the world energy crisis. While it also leads to the crisis of energy consumption, the main reason is still debatable among the researchers. However, the released of carbon emission in construction field is generally believed has triggered the phenomena and become the primary cause of global warming. It is proven that the building sector contributes to the biggest causes of overheating in the environment. Based on previous research, residential and commercial has reached 20% to 40% of the total energy consumption and this growing trend is still happening. Moreover, the electricity consumption in the building and construction process is the main reason for the growth of carbon emission. Therefore, the stakeholder particularly architects and designer should take an early initiative to overcome the problems. One of the approaches is to predict building performance through simulation in the initial design phase. In line with this, rapid technology development has brought to an alarming situation concerning energy consumption. Passive design is considered as one of the strategies to moderate indoor temperature in a tropical climate. Some studies suggest that the use of natural ventilation is potentially reducing operating costs and produce better thermal and indoor air quality. This study will investigate the optimization process of daylight performance condition that driven by façade components such as balcony size, orientation, openings, layout and louver windows using generative and parametric tools through multi-objectives optimization and generative simulation. The methodology used in this research is generative simulation in parametric platform named Grasshopper sith plugin software ladybug + honey bee. From the simulation it is resulted that Preferred individuals have an illuminance value of 211 test points. The properties owned by these individuals are cantilevered as a canopy at the height of 3 meters, a cantilever or canopy length of 2 meters, the building’s orientation angle to the south is 21 °, and has 32% opening of the total façade surface.

1. Introduction
The goals of indoor environment quality rely on the design of the façade, massing, and building orientation that potentially brings occupant well-being [1]. Thus, the proper approach should be taken considering environmental awareness since the early phase of architectural design processes. The tremendous development in the digital and computational design is one of the approaches to optimize the aspects of architectural design. The benefit of the use of building performance analysis is that architects can predict the building performance before the building constructed [2]. Moreover, the
The possibility of integrating design and the pursuit of sustainability can be done by incorporating building performance simulation in early design stages [3].

The project that will be carried out in this paper is a classroom located on the campus of the Sumatra Institute of Technology (ITERA), which will be simulated based on microclimate conditions in the city of Bandar Lampung. The simulation is done by applying several conditions both to the classroom and to the surrounding climatic conditions. This study intends to identify the optimal solution from the application of several design parameters, especially components in the building façade such as height and size of the canopy and the percentage of openings on each surface of the classroom module. Furthermore, the optimization process will be applied to the designated model using an optimization plugin in the parametric platform called Octopus.

The background of this research is that the use of generative platforms is felt to provide flexibility in the production of design solutions. Besides, when compared to the classical design process, this method allows architects to map obtained from the distribution of design solutions that cannot be produced from the usual design process. The research question is how high the canopy, the width of the building canopy orientation, and the percentage of windows that can provide a point distribution in a room that has illuminance with a range between 200 - 300 Lux, preferably 250 lux following the comfort standards in SNI 03-6575-2001 [4]. This research hypothesizes that integrating computational processes can result in the spread of an optimized population regarding the façade components.

2. Methodology

In this research, the methodology used is daylight analysis simulation using parametric platform software, Rhino Grasshopper. Honeybee and ladybug are used as media to change geometry into honeybee zones, which will be simulated through ladybug. The methodology begins with the study of design requirements and the information on the site. The actual data was obtained from Energyplus EPW file of Bandar Lampung, which contains historical weather data of the city. The research framework can be seen in Figure 2.

When the main geometry has decided, the next step would be regulating the constraints. Constrains, which is a parametric source, will be arranged to form the main geometry based on the parameters. In this research, forming the geometry by the system of the Generative Algorithm is described by the terminology of modelling. The main activities of this thesis are the arranging process of the Generative Algorithm components that has an integrated function related to the objectives and parameters. The overall system of the Generative Algorithm (Figure 3) is made in three major phases due to the different simulations to be performed. The first phase of the Algorithm is made to construct the main geometry. The second phase is the Algorithm for structural analysis, and the third is the Algorithm made for the Daylight analysis. Furthermore, finally, the Algorithm is made for the optimization process to filtrate the design solution of the generations of the structural and daylight analysis.
2.1 Object modelling

The simulation in this study was applied to the virtual model of a classroom with a size of 8m x 16m and height to the ceiling of 3.5m. This room module has been implemented several times in the construction of the ITERA campus. The proportion of length times width has a ratio of 2: 1 and is perceived to be at the height of 0.0m or on the 1st floor. The parameters used in this model are as follows:

| Component parameter       | Range         | Movement |
|---------------------------|---------------|----------|
| Cantilever Height         | 2.7m – 3.3m   | 6        |
| Cantilever Length         | 1m – 2m       | 11       |
| Rotation angle / Orientation | 0° – 40°     | 41       |
| Opening percentage        | 25% - 40%     | 15       |
2.2 Bandar Lampung conditions

Bandar Lampung is the capital city of Lampung province. It has a tropical climate with an average temperature of 23 - 37 °C. humidity is about 60% - 85% and is at a maximum altitude of 700 meters above sea level. The annual data of Bandar Lampung can be seen in Figure 5. Bandar Lampung city is classified in a zone that has a humid climate all over the year. Rainfall ranges between 2.257 - 2.454 mm/year. The air humidity ranged from 60% - 85% and the average temperature ranges from 23 - 37 °C. Wind velocity ranged from 2.78 - 3.80 knots with dominant direction from the west in November, from the north in March, from the east in June and from the south in September. For the analysis period, the hottest day of the whole year has been chosen, which is December 22 at 13:00 [5].

Figure 5. Dry Bulb Temperature, Relative Humidity and Direct Illuminance of Bandar Lampung
2.3 Simulation Platform

The platform used to do the simulation is a plugin that works on the Grasshopper software, Ladybug + Honeybee. A ladybug is a software used for environmental simulations. Ladybug was developed to facilitate designers and engineers to carry out environmental analysis quickly. Besides, Ladybug was created to integrate environmental analysis with the design process. Since this system is set to work in Grasshopper's parametric environment, it is hoped that this software helps justify design considerations concerning environmental simulations. Ladybug is an open-source plugin at Grasshopper that helps architects and engineers create architectural designs by involving environmental awareness. Importing Ladybug through Energy Plus Weather Files (EPW) into Grasshopper and providing various 3D interactive graphics to support the decision-making process in the early stages of design, Ladybug requires weather data from objects to be analyzed so that the validation of the results of the analysis is valid [6].

![Ladybug Framework](image1)

**Figure 6.** Ladybug framework

Honeybee connects Grasshopper to Energy Plus, Radiance, Daysim, and Open Studio to build energy simulations. The honeybee is intended to make this simulation feature available in a parametric platform. Analysis using the Ladybug + Honeybee is done after the virtual building model has been defined. The parametric modeling scheme using Ladybug + Honeybee in the overall algorithm system can be seen in Figure 7.

![Honeybee Framework](image2)

**Figure 7.** Honeybee framework
3. Results and Discussion

Another plugin that is integrated with Ladybug is Honeybee. Honeybee is software that works with Ladybug to work in simulating the Grasshopper system to other environments from energy simulation machines such as added energy, light, and others. Unlike Ladybug, Honeybee is used to defining information from the components and physical characteristics of objects for environmental and energy simulations.

Optimization on the Octopus platform is done with the elitism parameter 0.5, mutation probability 0.2, mutation rate 0.9, crossover rate 0.8 population size 100, and maximum generation 50. In this process, four parameters are set as genes, namely Cantilever Height, Cantilever lights, Angle of rotation for building orientation, and opening percentage. The results obtained from this process are population fields containing design solutions, each of which contains data related to the position of the tie movement parameters in the genes. The target sought is the highest number of test points with illuminance ranged from 200 lux to 300 lux. From the results obtained, the best solution that has a test point value with the targeted value is in the maximum position (top) quadrant axis 3. Preferred individuals have an illuminance value of 211 test points. The properties owned by these individuals are cantilevered as a canopy at the height of 3 meters, a cantilever or canopy length of 2 meters, the building's orientation angle to the south is 21°. It has 32% of the total surface opening of the façade building. The results of population distribution can be seen in Figure 8.

![Preferred individual](image.png)

**Figure 8.** Octopus 5 axis population field and preferred solution

The population above has five axes, including axis 1 for orientation angle, axis 2 for illuminance summary, axis 3 for cantilever length, axis 4 for opening percentage represented by gradations of color from green with low to red openings for larger openings. While the size of the mesh represents the axis five cantilever height, the smaller the mesh size, then it represents the position of the higher level.
Figure 9. Preferred individual (solution) represented with mesh and Delaunay front mesh

The preferred individual as a potential design solution furthermore being reinstated to see the parameter map and the legend spread in the built mesh.

Figure 10. Reinstate solution (perspective)  
Figure 11. Reinstate solution (top)
4. Conclusion
The integration of computational design in optimizing the façade component into daylight performance analysis has been discussed in this paper. Considering how multi-objective optimization used to support design decision-makers can provide more comprehensive alternatives in approaching the design decision phase. This study shows that the parameter movement can be iterated through the platform and can be analysed in the relative short of time compared to the classical design program, which is challenging to produce hundreds of design options for design and environmental consideration.

The simulation resulted in the condition of façade component features that have an illuminance value of 211 test points with an individual's features are windows canopy at the height of 3 meters, a cantilever, or canopy length of 2 meters, the building’s orientation angle to the south is 21°. It has a 32% glazing ratio of the total façade surface. The optimal number of test grid obtained from the generative optimization process is expected to have better performance compared to the solution produced using the classical design evaluation process.

Further study could incorporate more objectives such as surface radiation, Indoor thermal comfort, or shadow study to make the iteration more valid and complex. Besides, the platform not only can be used for analysing indoor performance but also to measure and simulate outdoor microclimate conditions using several factors in its parameters.

Acknowledgements
Authors would like to thank to Institut Teknologi Sumatera for providing the research grant No. B / 371 / IT9. C1 / PT. 01.03 / 2019 “Penelitian Hibah ITERA SMART 2019”

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