

# Parametric Louver Design System Based On Direct Solar Radiation Control Performance

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## Abstract

The purpose of this study is to develop a parametric design methodology that combines parametric design with thermal analysis. This new approach suggests that a form emerges from a performance based analysis. The result of the study is a parametric louver design system, which optimizes a louver form based on its direct solar radiation control performance. The system is composed of three parts: the analysis part, parametric design part, and optimization part. Each part functions interactively to produce an output. The output is the best performing louver form for the given site from the aspect of its yearly direct solar radiation control performance. The study applies the suggested design system to a case study, which is a virtual curtain wall office building in Seoul, Korea. The system produces the best performing louver form for each of the building's two main facades. The study compares the thermal performance of the best performing louver design with a commonly used louver design using a different software, Ecotect Analysis 2011. The Ecotect's thermal analysis confirms that the suggested louver forms perform better, reducing the building's heating and cooling loads.

**Keywords:** parametric louver design; optimization; direct solar radiation; performance

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## 1. Introduction

The formal composition of buildings has been explored in various ways in history. The Modernists' approach was to remove all the "decorative" elements in a building and to achieve a machine aesthetic through applying transparency and simplicity. Postmodernists, on the other hand, insisted on bringing back forgotten historic elements into architecture. The ideals behind these architectural movements may vary, yet they all depend on the architect's intuitive design decisions in terms of form making. There is an emerging approach in the discussion of form making that departs from the old tradition of intuition-based design, which is Performative Architecture. This new movement utilizes digital technologies of quantitative and qualitative performance-based simulation to offer a comprehensive new approach to the design of the built environment. (Kolarevic & Malkawi, 2005) This study shares the theoretical background with Performative Architecture as its goal is to find the best performing louver form from the aspect of direct solar radiation control performance.

Exterior louvers are effective devices to reduce the building's cooling loads in the summer. The best way to reduce the building envelope's solar heat gain is to block it before it reaches the glazed surface. However, if the louver design does not reflect the sun's yearly path, it blocks the desired winter sun as well, increasing the building's heating load.

It is hard to set a rule for designing a louver, since the best form of a louver cannot be fixed to a single shape as it is affected by many variables; the weather condition, orientation of the glazed surface, physical surroundings, etc. It is widely believed that horizontal blades are good for a south facing surface, and vertical fins are good for east and west facing surfaces. Then, what kind of louvers should one use for southwest, or southeast facing surfaces? Furthermore, how should one decide the formal specifics of the louvers? Projection length, spacing, inclination, angle of rotation, to name just a few. (Choi, Lee, Ahn, Piao, and Lim, 2013a)

There is not much information available for architects about how to design well performing louvers. Often louvers are designed based on the architect's intuitive design decisions. The motivation behind this research is to create a system that helps architects to make more accurate design decisions. Based on the quantitative performance simulations, the system offers the best performing louver form for the given glazed surface. As shown in a concept diagram (Fig.1.), the

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system is composed of three parts: the analysis part, the parametric design part, and the optimization part. Each part is connected to the others interactively, and they respond to each other to find the best performing louver form.

## 2. Direct Solar Radiation Control Performance

This study is developed using a widely used scripting editor, Grasshopper. Grasshopper is a graphical algorithm editor that can be used within Rhinoceros 3D. Rhinoceros 3D is one of the commonly used 3D modeling software in the field of architecture, and Grasshopper is an easily accessible software, requiring no knowledge of programming or scripting. (Choi, Ahn, Lee, Shin and Lim, 2013)

In order to analyze the louver's direct solar radiation control performance, the system uses the evaluation algorithm previously developed and documented in "An Evaluation System for Thermal Performance of Parametric Exterior Louver Design Alternatives." (Choi, Ahn, Lee, Shin and Lim, 2013) The best louver design should block summer sun and let winter sun through. It is important to conduct a simulation in a yearly setting, because if one only looks at the data of how well the louver blocks the sun, it is possible to oversee the problem of the increased heating load being greater than the reduced cooling load. Therefore the goal of this research is to find a louver form that lets winter sun through, and that blocks summer sun depending on the outside temperature.

In order to analyze the louver's yearly direct solar radiation control performance, the system uses TMY (Typical Meteorological Year) weather data offered by the Korean Solar Energy Society (2009). Korean TMY is the hourly weather data of South Korea made by the TRY (Test Reference Year) method that uses weather data from 1986 to 2005. It offers dry bulb temperature, humidity, horizontal direct solar radiation, and many more. (Choi, Ahn, Lee, Shin and Lim, 2013) The system takes outside temperature and horizontal direct solar radiation information from TMY weather data

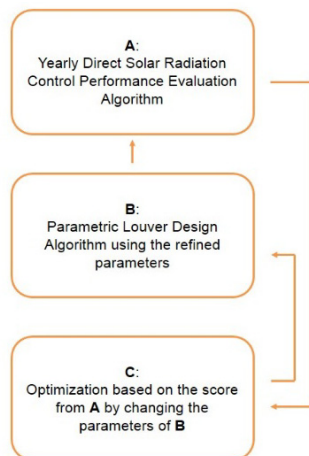


Fig.1. Parametric Louver Design System (concept diagram)

to calculate direct solar radiation gain on the glazed surface.

## 3. Parametric Louver Design System

### 3.1 Analysis

Exterior louvers do not have much impact on indirect solar radiation and conduction, as they have a small surface area attached to the glazed surface. Therefore the system only considers the heat gain through direct solar radiation.

In order to find a louver form that blocks the summer sun and lets winter sun through, it divides a year into three different seasons; heating season, cooling season, and in between season. These seasons are defined by setting a low temperature and a high temperature. For example, if the low temperature is set at 10°C and the high temperature is set at 20°C, it means that every hour with outside temperature lower than 10 degrees Celsius falls into the heating season. On the other hand, every hour that has outside temperature higher than 20 degrees Celsius is considered as the cooling season. The temperature setting is not fixed as constants, and it can be changed anytime. (Choi, Ahn, Lee, Shin and Lim, 2013)

The evaluation algorithm calculates the Best Case Scenario for the given surface. The Best Case Scenario is defined as receiving all the winter sun on the glazed surface and blocking all the summer sun on the given surface. As the amount of heat gain changes according to the surface's location, orientation, and physical surroundings, the Best Case Scenario is different for every given case. (Choi, Ahn, Lee, Shin and Lim, 2013) The calculation of the Best Case Scenario provides a reference point to produce scores for each louver design created by the second part of the system.

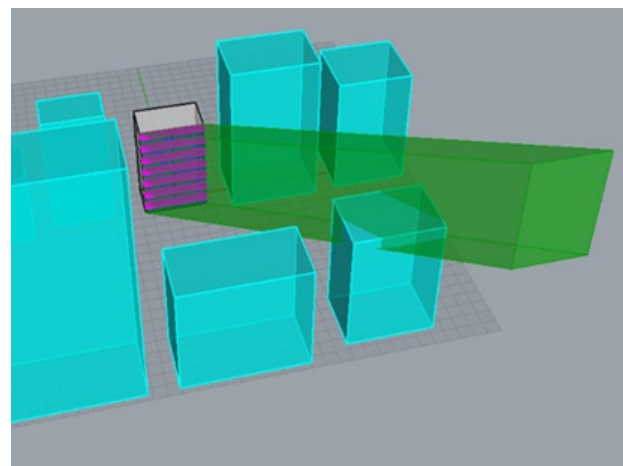


Fig.2. Evaluation of Direct Solar Radiation Process

The system evaluates the louver's performance based on the glazed surface's heat gain. The system calculates the area of heat gain on the glazed surface every hour for the entire year (Fig.2.). In order to do this, a user needs to build an accurate 3D model of the building

and the site. The user specifies the orientation of the glazed surface and selects a city. If the calculated hour falls into the heating season, it will compare the result with the Best Case Scenario to see how much more heat the louver should have let through. If the calculated hour falls into the cooling season, it will compare the result with the Best Case Scenario to see how much more heat the louver should have blocked.

### 3.2 Parametric Louver Design

A set of formal parameters that compose the parametric louver design algorithm has been previously defined and documented in "Evaluation of Parameters for Louver Design Algorithm based on Direct Solar Radiation Control Performance." (Choi, Lee, Ahn, Piao, and Lim, 2013a) All the architectural journal papers published in Korea have been searched to find all the possible formal parameters of the exterior louvers. As a result, six formal parameters are set to go through a parameter sensitivity test. The six parameters are as follows: Angle of Rotation, Coverage Ratio, Spacing, Distance from Glazing, Projection Length, and Inclination. (Figs.3. and 4.)

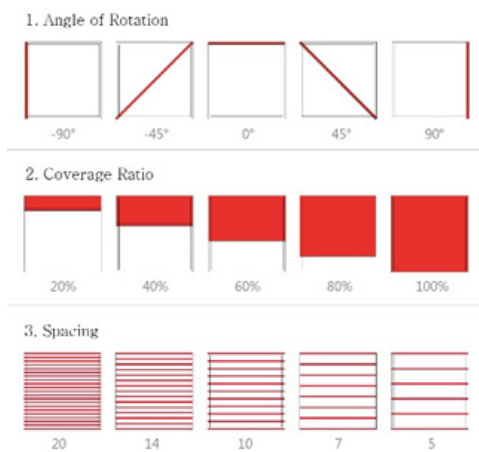


Fig.3. Six Formal Parameters (1)

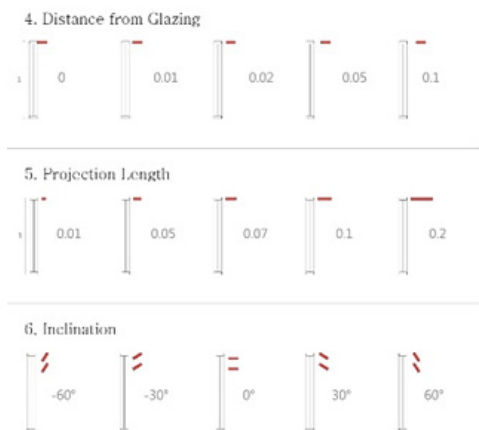


Fig.4. Six Formal Parameters (2)

After conducting a parameter sensitivity test, five parameters are found to be significant. Among the five, one parameter can be changed into a constant of

100%, leaving a short list of four parameters as valid: Angle of Rotation, Spacing, Projection Length, and Inclination. (Choi, Lee, Ahn, Piao, and Lim, 2013a)

The four newly defined parameters compose a parametric louver design algorithm. The louver form changes as the parameters change. For example, a user may change the angle of rotation to make the louver from a vertical fin to a horizontal blade, or in between. The changes may happen incrementally or even in a continuous way.

### 3.3 Optimization

Optimization part of the system uses a genetic algorithm to find the best performing louver form. The structure of the system is as follows. The parametric louver design algorithm is connected to the evaluation algorithm. The genetic algorithm is connected to the parameter part of the parametric louver design algorithm, and the output part of the evaluation algorithm. The genetic algorithm will change the parameter settings randomly, and for every change made, the evaluation algorithm will produce a score. The genetic algorithm will then try all the possible combinations to find a parameter setting with the best score.

## 4. Case Study

### 4.1 Setting

A case study has been conducted to confirm how the Parametric Louver Design System works. The case study is done as follows. First step is to set a building for the analysis. Second step is to apply the parametric louver design system and find the best performing louver form for the each façade. Third step is to compare the building's heating and cooling loads of the different louver conditions by using Autodesk's Ecotect Analysis 2011.

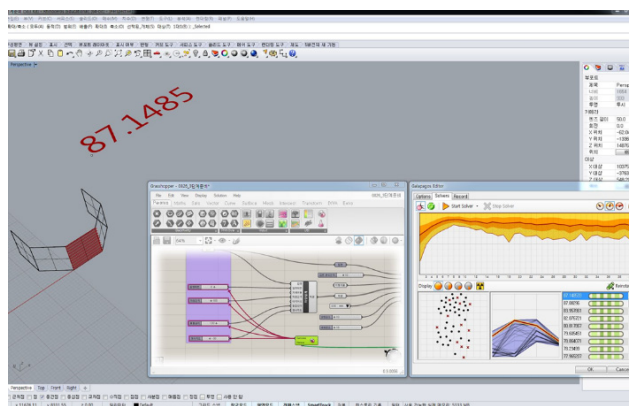


Fig.5. Evolutionary Computing Process

A medium size virtual curtain wall office building has been created in Rhinoceros 3D. The building stands at the northeast corner of an intersection, having south and west facing facades. (Fig.6.). The location of the building is set as Seoul, Korea. The building is 40 meters x 30 meters in plan and 10 stories high. The

south façade and the west façade are glazed surfaces, and the north and east walls are reinforced concrete walls (Table 1.). To compare the output of the system with existing louver forms, vertical fins are placed on the west façade and horizontal blades are placed on the south façade. The most commonly used louver forms are applied for the existing louver design (Tables 2. and 3.).

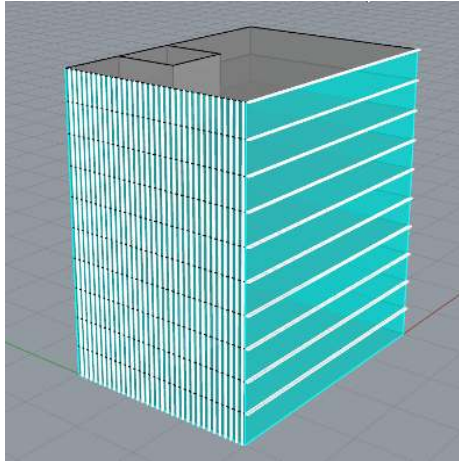


Fig.6. Virtual Building with Existing Louver Design

By using the parametric louver design system, the best performing louver forms are produced for the two glazed surfaces of the virtual building. The system offers numerous louver forms and their scores. If a user chooses the best score, the system automatically creates the corresponding louver form (Fig.7.).

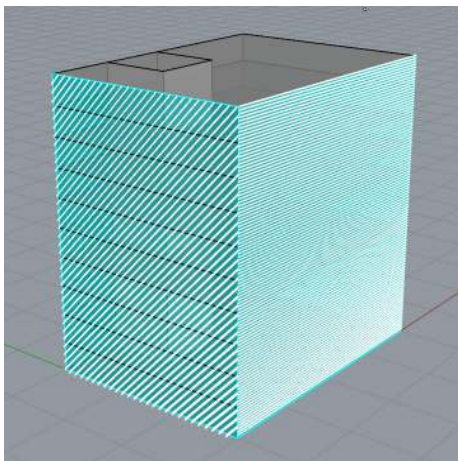


Fig.7. Best Performing Louver Design

The Best Performing Louver Design for the south façade is a horizontal blade with spacing at 400mm, projection length at 240mm, and inclination at 31° (Table 4.). The Best Performing Louver Design for the west façade is a diagonal blade at -45° angle with spacing at 780mm, projection length at 500mm, and inclination at 25° (Table 5.).

Table 1. Virtual Building Design

Building	Specifics
Floors	10
Floor to Floor Height	4m
Architectural area	1200m <sup>2</sup>
Gross Area	12000m <sup>2</sup>
Curtain Wall	South, West

Table 2. Existing Louver Design (South)

Formal Parameters	Specifics
Angle of Rotation	0°
Spacing	4000 mm
Projection Length	500 mm
Inclination	0°

Table 3. Existing Louver Design (West)

Formal Parameters	Specifics
Angle of Rotation	90°
Spacing	900 mm
Projection Length	300 mm
Inclination	0°

Table 4. Best Performing Louver Design (South)

Formal Parameters	Specifics
Angle of Rotation	0°
Spacing	400 mm
Projection Length	240 mm
Inclination	31°

Table 5. Best Performing Louver Design (West)

Formal Parameters	Specifics
Angle of Rotation	-45°
Spacing	780 mm
Projection Length	500 mm
Inclination	25°

Table 6. Ecotect Material Setting

Building Element	Material
Roof	Concrete Roof Asphalt
Floor	Concrete Floor Tiles Suspended
Ceiling	Plaster Insulation Suspended
Wall	Concrete Block Plaster
Window	Single Glazed Aluminum Frame
Louver	Solid Timber

## 4.2 Result

The evaluation algorithm of the system gives the existing louver designs lower scores than the best performing louver designs (Table 7.). The result shows that the existing louver design for the west façade is worse than no louver condition. The best performing louver designs have the highest scores compared to the no louver conditions and the existing louver designs in both south and west facades.

In order to confirm that the louver design derived from performance based simulations saves more energy than the design made by an architect's intuitive design decisions, a thermal analysis using a different software has been conducted.

## 4.3 Ecotect

A performance evaluation program is needed to compare the different louver designs and their impact on the building's heating and cooling loads.

Table 7. Scores of Different Louver Conditions (Parametric Louver Design System)

Facades	No Louver	Existing Louver Design	Best Performing Louver Design
South	71	74	86
West	34	29	89

Table 8. Thermal Analysis of Different Louver Conditions (Ecotect Analysis 2011)

Month	No Louver			Existing Louver Design			Best Performing Louver Design		
	Heating (Wh)	Cooling (Wh)	Total (Wh)	Heating (Wh)	Cooling (Wh)	Total (Wh)	Heating (Wh)	Cooling (Wh)	Total (Wh)
Jan	120,171,344	0	120,171,344	120,892,728	0	120,892,728	121,919,240		121,919,240
Feb	79,700,600	0	79,700,600	80,484,840	0	80,484,840	81,604,232		81,604,232
Mar	22,923,014	0	22,923,014	23,231,426	0	23,231,426	23,685,820		23,685,820
Apr	856,116	17,660,054	18,516,170	883,996	17,258,488	18,142,484	930,589	16,226,335	17,156,924
May	0	101,263,200	101,263,200	0	100,147,776	100,147,776		98,543,800	98,543,800
Jun	0	144,595,632	144,595,632	0	143,263,120	143,263,120		141,373,952	141,373,952
Jul	0	169,175,968	169,175,968	0	167,931,904	167,931,904		166,166,672	166,166,672
Aug	0	181,620,064	181,620,064	0	180,358,448	180,358,448		178,570,896	178,570,896
Sep	0	135,605,792	135,605,792	0	134,551,520	134,551,520		133,057,856	133,057,856
Oct	180,337	65,143,820	65,324,156	182,707	64,162,996	64,345,704	185,926	63,050,560	63,236,484
Nov	21,498,240	334,979	21,833,220	21,788,126	332,552	22,120,678	22,203,150	326,957	22,530,106
Dec	87,605,304	0	87,605,304	88,313,872	0	88,313,872	89,323,656		89,323,656
<b>Total</b>	<b>332,934,944</b>	<b>815,399,424</b>	<b>1,148,334,336</b>	<b>335,777,696</b>	<b>808,006,848</b>	<b>1,143,784,576</b>	<b>339,852,608</b>	<b>797,317,056</b>	<b>1,137,169,664</b>
<b>PER m<sup>2</sup></b>	<b>27,745</b>	<b>67,950</b>	<b>95,695</b>	<b>27,981</b>	<b>67,334</b>	<b>95,315</b>	<b>28,321</b>	<b>66,443</b>	<b>94,764</b>

Therefore, Ecotect Analysis 2011 by Autodesk has been selected to conduct the evaluation. Ecotect has several major functions. It offers Daylighting Analysis, Thermal Performance Analysis, Water Usage and Cost Evaluation, Solar Radiation, to name just a few. Ecotect has been chosen even though it is not highly accurate engineering software, because it is quick and easy to use. For this reason, it is one of the most widely used energy analysis software.

For this research, Ecotect's Thermal Analysis function has been used to see the changes in the building's heating and cooling loads according to the different louver conditions.

The setting for the analysis is as follows. Under the Internal Design Conditions, Clothing is set as Business Suit, Humidity as 60%, Air Speed as 0.5 m/s, and Lighting Level as 600 lux. Under the Occupancy and Operation, the building is set as an office building operating from Monday to Friday between 8am and 7pm. Number of people and Activity are set as 1 person/8m<sup>2</sup> and Clerical work (70W). Interior heat gain through computers and electronics is set as 35w/m<sup>2</sup>. Desired thermostat range is 18°C to 26°C. The material setting for the building is specified in Table 6.

Using the above explained setting, thermal analysis for the three different louver conditions have been

conducted; No louver condition, existing louver design condition, and the best performing louver design condition. The result of the analysis is shown in the building's monthly heating and cooling loads (Table 8.).

According to the result, No louver condition has the highest total loads, the existing louver design has the second highest total loads, and the best performing louver design has the lowest total loads. The building's thermal loads have been reduced 931 (Wh) per m<sup>2</sup> in a year by installing the best performing louver design.

The analysis has confirmed that the best performing louver design reduces the building's heating and cooling loads. The decrease in the cooling load is greater than the increase in the heating load, therefore, it reduces the building's overall energy use.

## 5. Conclusion

This study explores new ways to design an exterior louver. Conventionally, a louver design has been done by an architect's intuitive design decision, not considering the design's thermal performance. The study presents a parametric louver design system that is composed of three parts: analysis part, parametric louver design part, and optimization part. This system finds the best performing louver forms for any given site. The system reflects the physical surroundings,

local climate data, and the orientation of the site to conduct direct solar radiation simulation. This system calculates which louver form controls the direct solar radiation the best and offers a solution for the user.

A case study has been done to prove that the system works at the reality level. The case study has compared the commonly used louver designs with the system's own findings. The system has evaluated its own findings superior to the existing louver designs. The Ecotect analysis has also confirmed that the system's findings are superior to the existing louver designs as well as the no louver conditions.

Though the system is still at its infancy, and there are limitations. However, it explores the new design methodology that a form can emerge from a performance based simulation.

Along with the growing concerns about the environmental issues, there are various attempts to reduce existing buildings' energy consumption. This system can suggest reasonable solutions to reduce their energy use.

### Acknowledgements

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