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Effect of Adaptive Facades on Daylight -An Analytical Study in Hot Arid Climate

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Abstract:
Adaptive façades respond to outdoor and indoor stimuli to provide a design solution that enhances the visual comfort of office space[1].The visual comfort is improved by solving useful daylight illuminance and glare simulation, which is performed in this paper using Rhino software, algorithmic modelling by Grasshopper and Diva with Galapagos interface to explore the applicability of parametric design to increase daylight performance and decrease glare[2].

The principal aim of this paper is to estimate the effect of sunscreen configuration on achieving a balance between enough illuminance level and glare uniformity inside a selected space.

Keywords:
Visual comfort; Glare; Daylighting; Adaptive façade; Rhino software

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1. Introduction:

Adaptable façades are the next landmark in façade technology and expanding consideration by academics. By definition, An adaptive façade can repeatedly and reversibly change some of its functions, features or behaviour over time in response to changing performance requirements and variable boundary conditions [3].

Many types of adaptive façade concepts are developed the new concept growths. However, adaptive façade skin is not a well-defined of architectural study. Just to mention a few examples, it ranges from artificial intelligence to passive design, from responsive art connections to media facades, and it offers a subtle composition of façade elements for optimizing the daylighting and solar insolation. The International Energy Agency has started research efforts for Advanced Integrated façade, Double Skin Façades and Responsive Façade [4] .a centric as comfort design from the suitable combination by the parametric strategy is the main idea to ASF [2].

According to Köppen's climate map, the Egyptian atmosphere is named a desert hot arid climate. This climatic zone is described by solar abundance throughout the year and high irradiation potential. This level of long solar hours, approximately from 9 to 12 hours daily, provides a good opportunity for building designers to utilize such abundant daylight for use in natural light inside buildings' spaces to lower energy consumption[5].

The dynamic nature of daylighting, during the day and the year, poses numerous challenges when designing buildings that seek to utilize this abundant natural resource to meet the illuminance requirements of architectural spaces[6]. Obtaining daylight can produce not only high solar gain but also non-uniform daylighting distribution which leads to the phenomena that caused glare. The problem is that most solar screens in the Middle East are not well designed for the climate they are in. That shows the problem of the ongoing design trend of fully glazed office buildings in Egypt. Therefore, daylight penetration needs to be controlled by properly designed screens to get used to high solar radiation and decrease artificial lighting so decreasing energy consumption.

Recent progress in computer science and stringent requirements of the design of sustainable "greener" buildings put forwards the research and applications of simulation based optimization methods in the building sector, A methodology known as 'parametric simulation method' can be used to improve building performance .

Key discussions are focused on handling discontinuous multi-model building optimization problems, the performance, and selection of optimization algorithms, multi-objective optimization, the application of surrogate models, optimization under uncertainty and the propagation of optimization techniques into real-world design challenges[7].

2. DAYLIGHTING AND SIMULATION

The literature review shows two common sorts of metrics static daylight metrics and dynamic, are used for facade daylight valuation. Static metrics use a single calculation method in a specific time of day. They focus on individual sky conditions. On the other hand, dynamic metrics use an annual calculation method to describe the variability of daylight over a year[8].Dynamic metrics can be examined for seasons, time of day, and building orientations concerning responsive facade systems. Recorded climate data in the form of Local Energy Plus Weather Files (EPW files) are utilized to measure dynamic metrics[9].

2.1. Static Daylight metrics

Daylight factor (DF) is one of the most communal quantitative static metrics that commonly used to study daylight performance as a quantity metric. That well-defined as the ratio of daylighting to unshaded & exterior illuminance below a standard uniform sky. The calculation of DF depends on the split-flux method that is contingent on indirect sunlight [8].

A simulation tool climate-based daylight metrics (CBDM) was developed by building rating systems and standards. Another engine named DAYSIM was developed, which can calculate the annual simulation of daylighting that represents a step towards the best result for daylighting instead of Daylight Factor (DF) metric or point in time illuminance calculations and it is it considered revolutionary in the field of daylighting simulation[10].

2.2 Dynamic metrics

A metric is some mathematical combination of (potentially disparate) measurements and/or dimensions and/or conditions represented on a continuous scale [11].

The focal benefit for dynamic daylight concert metrics; related to statics is that reflected the quantity of regular day & seasonal discrepancies for daylighting to a certain both building site.

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2.2.1UDI: A human factors-based as a metrics

This metric estimates the daylighting ability was named as useful daylight illuminance, UDI which reached is well-defined as:

Annual incidence illuminances which across the plane that inside a variety measured the word useful by inhabitants, therefore illuminances in range one hundred to 300 lux. These values-based on investigations approved out in office buildings that glare on pictorial display strategies is public problematic [12].

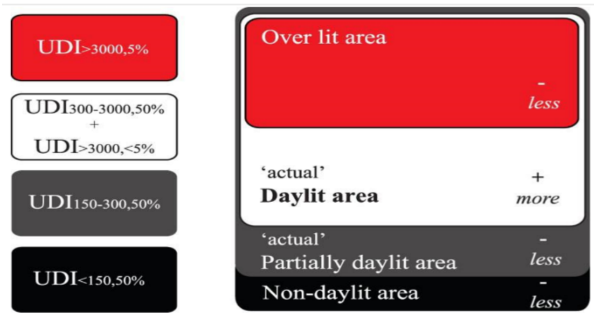

Figure 1. Daylight metrics and objective function[12].

When light is poorly distributed (Under lit area), parts of the ceiling and general surroundings will seem dark and gloomy. Substantial differences in light levels force your eyes to readjust when moving from one light level to the other. Workers may find it difficult or impossible to see properly [13]

2.2.2 glare metrics:

Most glare research has been concentrating on glare from various electric light sources, but specifically related to glare from daylight because of its variation in luminance and patterns. Such as in daylight situations, the window causes glare, because the luminance is often not uniform and quite high, especially if direct sunlight occurs, and frequently covers a large part of the visual field. as computer screen and windows are both in vertical planes and frequently in proximity. The direct beam illuminance, reflections and luminance in the part of the window area dominated by the sky is frequently very high, which causes a large luminance contrast between the window and the computer screen, there are Different existing indices:

- British Glare index (BGI).
- Discomfort Glare Index (DGI); to focus on contrast rather than brightness.
- CIE Glare Index (CGI).
- Unified Glare Rating (UGR).

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- Discomfort Glare Probability DGP.
- DGPs; to emphasis on brightness.
- Predicted Glare Sensation Vote (PGSV).
- DGP considers most parameters that affect the glare sensation[14].

3. Methodology

3.1 Simulation software and modeling tools

The workflow developed in this paper started with the generation of a 3D model of the office space using Grasshopper, which is a plug-in for Rhinoceros. Galapagos which is a genetic optimization algorithm that was used to automate and optimize the daylighting and glare simulations in Grasshopper[15]. While the simulations were running, a live connection with Excel was established to document the simulation results and the corresponding model parameter. This allowed for a case-by-case examination of results. By TT Toolbox plug-in, it is also composed, containing a variety of architectural software and hardware. The following sections provide an overview of the methodologies that were essential to simulation.

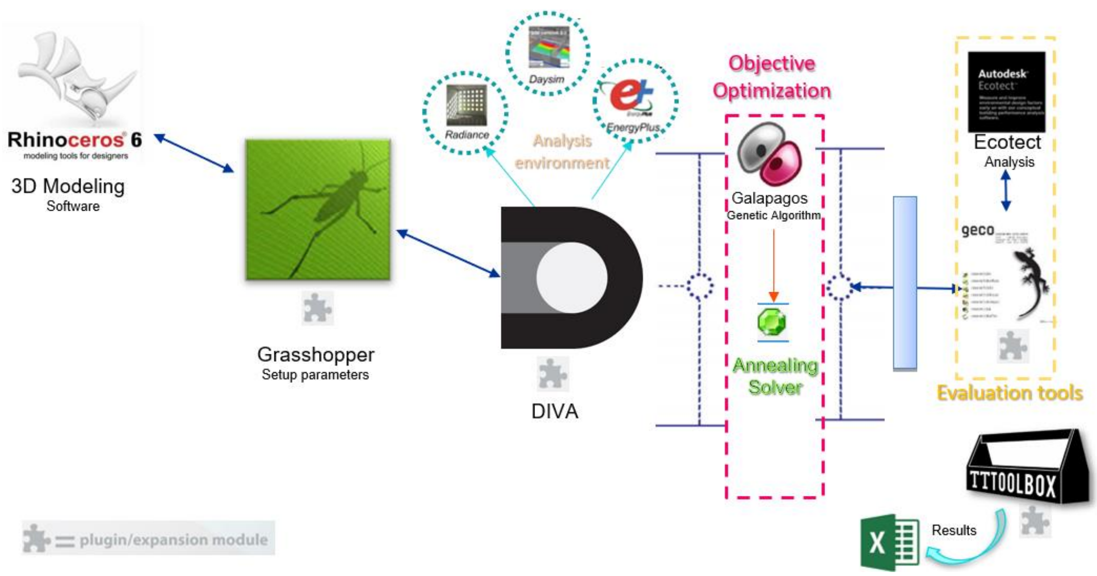

Figure 2. optimization tools by the researcher

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3.2. Site Analysis of office space

The case study was selected to be in Cairo, Egypt (30°6′N, 31°24′E, ALT. 75m). Cairo includes many offices and commercial buildings. On the other hand, it belongs to a subtropical desert arid, hot climate as mentioned in Köppen's climate classification which is characterized by high direct solar radiation and clear sky that demands special façade treatments to provide appropriate daylighting[16].

Simulation model parameters

The cell office is a side lit space facing the Southwest direction on the first floor. A simple test room is used for the annual, monthly daylight glare and UDI calculation. By using Rhinoceros and Grasshopper, a model was formed in the indoor office space of a single office zone. The parameters are as follows: 6m width,5,8m length and 3.45m height, with a total area is 20 m^2, it is a simple model representing an office cell. It is occupied on weekdays from 8am to 5pm. (9 people). in this research it has nine workplaces and a south-western oriented window.

3.3Base Case Simulation (before adding solutions):

3.3.1Field of View

The view positions of the front workplace will choose one view for use in the calculation. The distance between the view position and façade that is equal to 1.4 m at 1.2 m height, for the position (A) we will measure the ratio of brightness, it will produce a background illumination in the image which tends to mask the grain contrast effect. position (B) measure the ratio of glare: discomfort glare perception from the luminance of the glare source, relative to position (C) we will quantify the amount of Illuminance because of The position is far from the window

To achieve LEED 4 glare should be controlled, considering the Annual Sunlight Exposure (ASE) [17], In this study, DGP is calculated based on a simplified equation as DGPs based on vertical illuminance (Ev) data at the height of 1.2 m at each point of the evaluation grid. This metric evaluates the overall impact of vertical illuminance, including transmitted direct, and diffuse light and contribution from interior reflections [18].

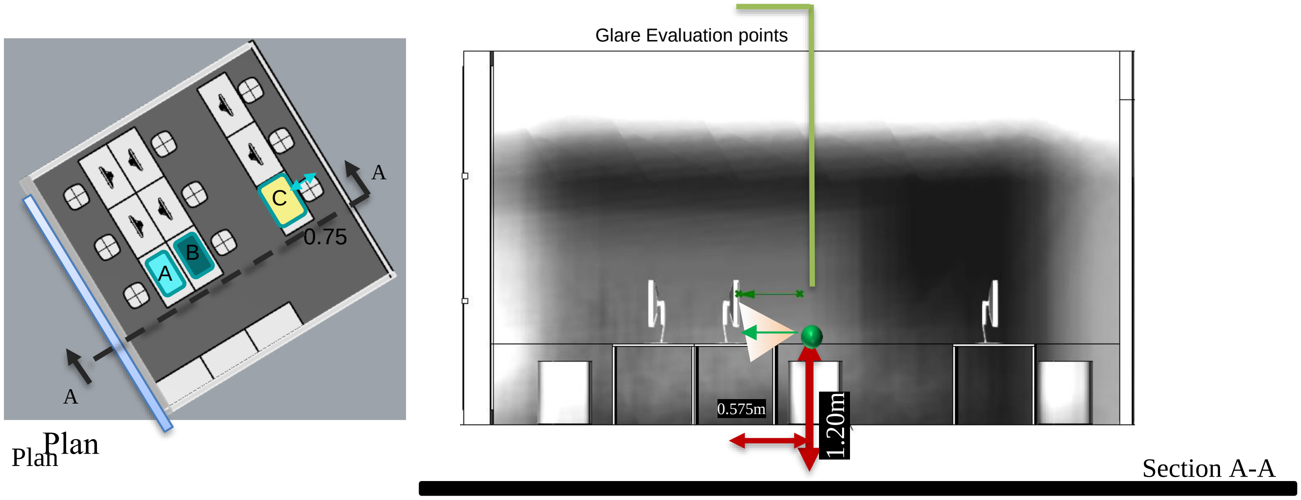

Figure 3.The DGPs needs only the awareness of $\mathbf{E_v}$ and it excludes effect of direct glare sources; therefore, it could be used solely when the sun is not in the field of view and there were no specular reflectance in the scene.

3.3.2 Annual glare evaluation: Impact of weather file selection

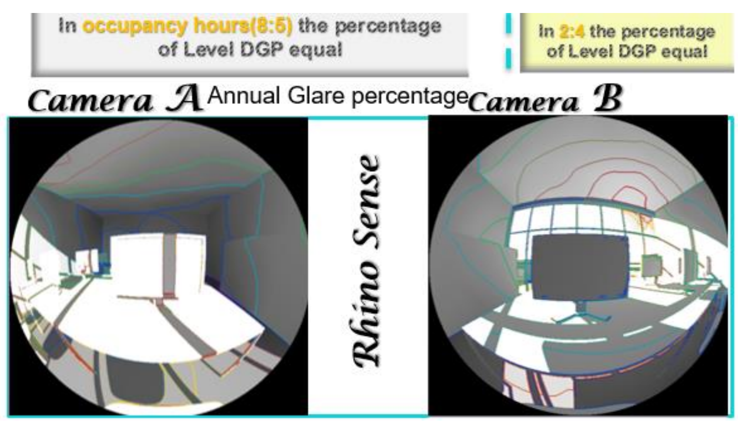

Figure 4. Annual daylight glare probability computed for a view (this particular view is exposed to disturbing/intolerable glare for a significant number of daylight hours)

The view position of the front workplace shown in (camera B) is the only view position selected to be used in the calculation. The calculations based on the distance between the view position and façade that is equal to 1.4 m at 1.2 m height (eye level).

Annual simulations show opposite results in some months, particularly from June to December. These are opposing results in the prediction of the time. Then, the camera B is recommended for use. A comparative analysis of the total amount of daylight glare accursed (Disability glare), the worst case was at 2 pm in winter.

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simulation phases

Results are divided in two parts: Calibration Phase, Optimization Phase and Validation Phase.

i. At the initial calibration stage: divided into two parts: for finding the monthly simulations for both UDI, DGP for the adaptive pattern in Galapagos annealing using Gecko Plugin For sun-tracking system as equation.

ii. The second Optimization stage is evaluating all cases

3.4. **Adaptive Screen design**

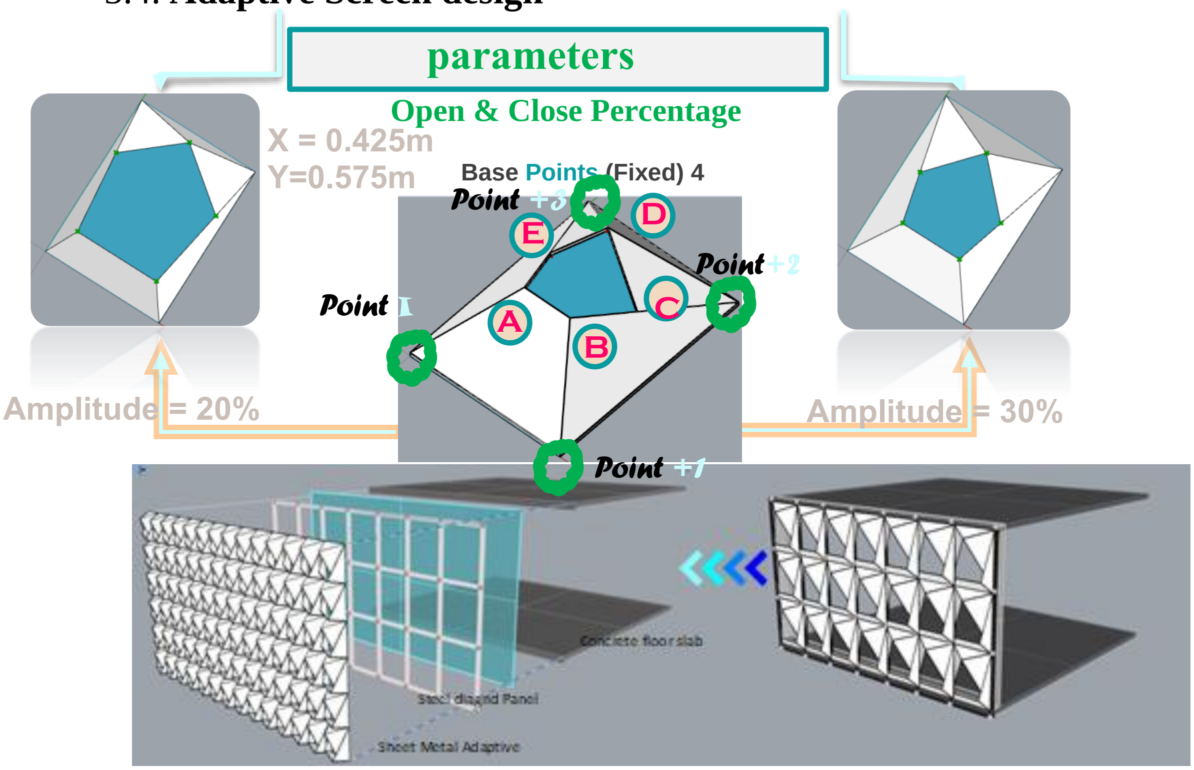

Figure 5. adaptive pattern screen

To test the proposed methodology, an adaptive solar screen was developed that consisted of a modular grid of hollow boxes, referred to as adaptive solar screen. This was used as a case study to enable consistent comparisons between adaptive shading and the base case.

The main screen module was generated by a series of commands; Amplitude (x), Amplitude (y), depth and surfaces' filling where one module is drawn in different degrees.

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3.5. monthly Simulations

i. the Optimization stage is divided into two parts to find monthly simulations for both UDI, DGP for the adaptive pattern screen in Galapagos annealing using Gecko Plugin For sun-tracking system as the following equation:

First equation: $\mathbf{if}(\mathbf{x} < 0.40{,}1{,}0)$ **for** Minimize DJP (1)

Second equation: $\mathbf{if}(\mathbf{x} > 85\%, 1{,}0)$ **for** maximize UDI (2)

The aim of simulation in this section is to offer a workflow to get each of the optimum energy consumption for daylighting and glare. So the function DGP has been deduced equation 1, where DGP stands for the daylight glare probability, in Galapagos optimization DGP consider fitness value in which Minimize it , if the fitness value (x in this equation) less than 40% (perceptible glare) the result will be partially acceptable , equal 1 else fitness value (x in this equation) more than 40% the result will be refused. Optimal façade configuration is known as input parameters for the simulation.

The goal in equation 2 is that UDI is a main factor as daylight optimization has an amazing effect on energy consumption. UDI in this equation consider fitness value in which Maximize it, if the fitness value (x in this equation) more than 85% the result will be partially acceptable , equal one 1 else fitness value (x in this equation)less than 85% the result will be refused(equal 0).Thus, a single-objective optimization was applied to develop the optimum solution for both criteria DGP and UDI. then a mathematical addition was done in order to find the final result, if it equal 2 it is completely accepted, having the opportunity to compare the result with a plugin (tt tool box) in excel and after that; select the best one which means that more than one objective research is needed for more efficiency.

4. RESULTS AND DISCUSSION

Comparing stage

The next step is comparing two adaptive screen types, Wavy pattern screen controlled by sin curve attractor and pattern screen controlled by point attractor to choose the best adaptive screen in June & December by using Galapagos for both UDI, DGP.

Part one:

The results of UDI & DGP for Wavy pattern screen controlled by sin curve attractor in June & December by Galapagos annealing.

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- **Firstly:** The optimization process will be displayed of Galapagos annealing for 1000 continuous trial.
- **Secondly:** The results of 1000 continuous trial will be analyzed in charts by (tt tool box) plugin and excel program.
- **Finally:** The best result will be displayed.

A- The results of UDI & DGP for Wavy pattern screen controlled by sin curve attractor in June.

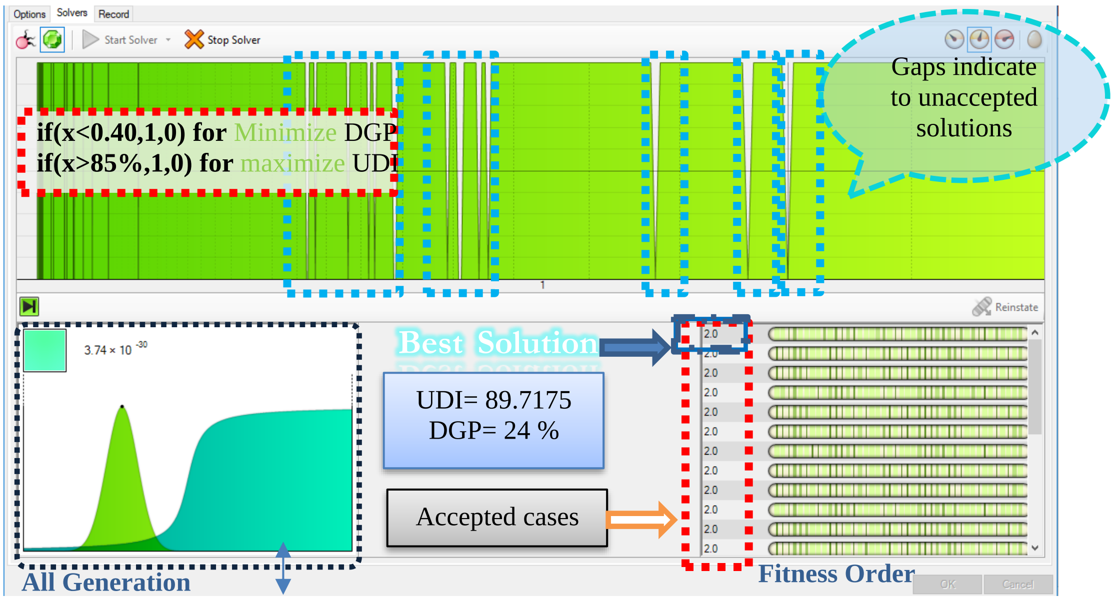

Figure 6. The Galapagos annealing interface for 1000 continuous trial. The results of trial values after 1000 continuous trial, 996 of trial is equal 2. Galapagos Species Record after 31 hours simulation.

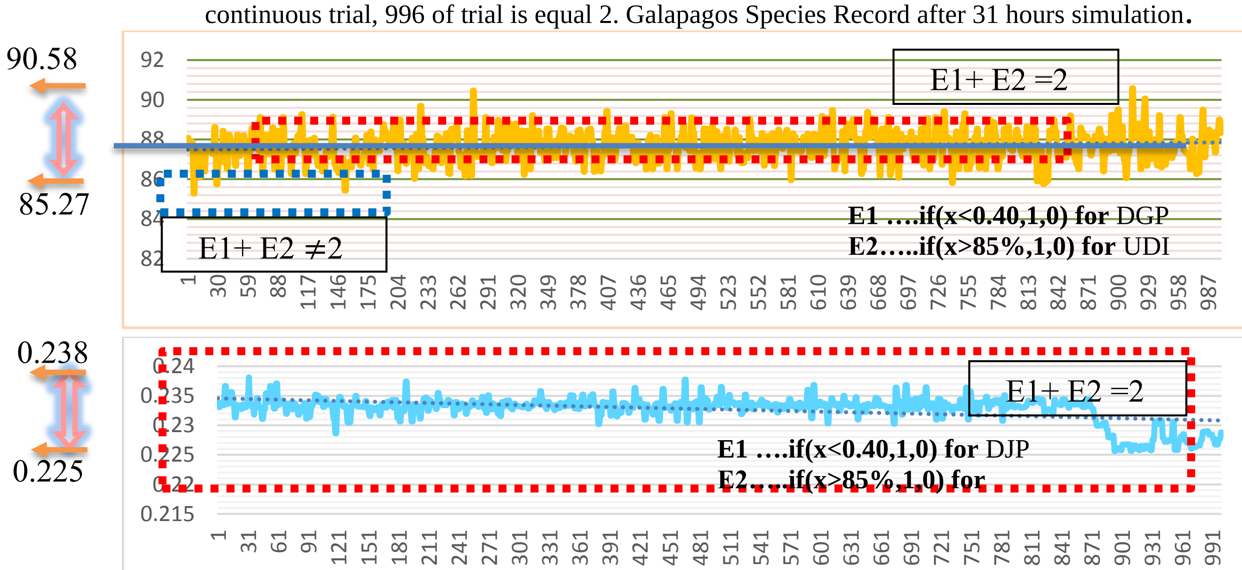

Figure 7. Optimization results for according to UDI and DGP metrics

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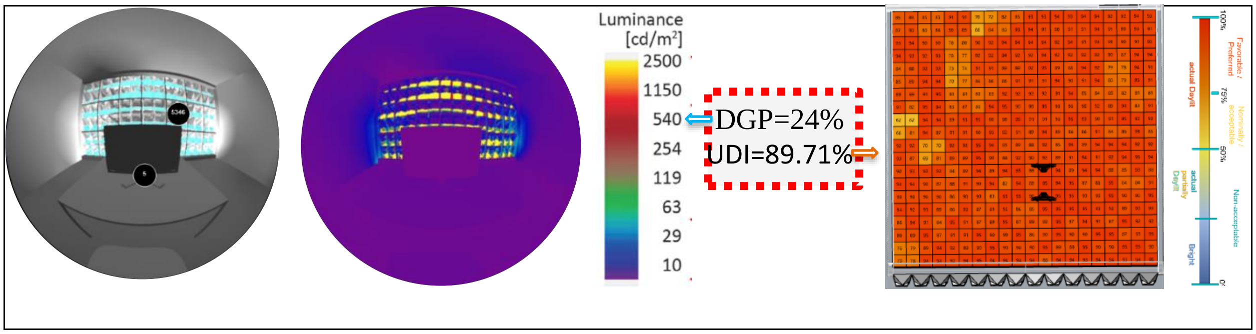
The results of UDI values after 1000 continuous, 6 of trial is more than 90% (according leed 4 point3),1000 of trial is more than 85% min is 85.275, max is 90.5825, average is 87.6721 ,The best value is 0.24 for DGP with 89.7175for UDI and The results of DGP values 1000 of trial is less than 40%,933 of trial is less than 23.5% ,min is 0.225628, max is 0.238127, average is 0.23269 .

Table 1.The Best result of DGP for Wavy pattern screen controlled by sin curve attractor in June.



For UDI: simulation results were ordered from the optimized performance to the worst ones. the optimized performance achieved average 89.71% and 67.916% daylit area in deepest space, with 28.419% of partially-daylit and 2.165% over lit areas.

wavy pattern with (open percentage for zone A min =40%,max=60%, for zone B min =20%,max=45% and for zone C min =40%,max=50%): achieved the best performance of the 1000 trial, and reached the acceptance DGP of imperceptible glare 24%.

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B-The results of UDI & DGP for Wavy pattern screen controlled by sin curve attractor in December.

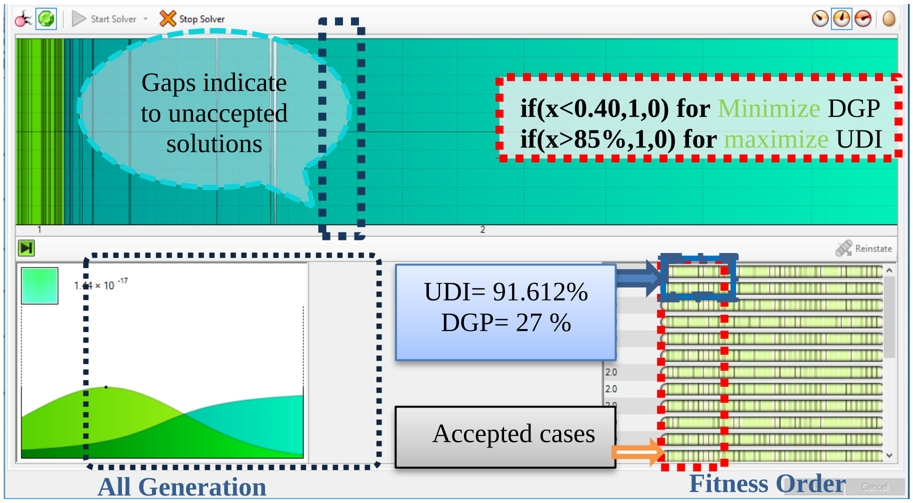

Figure 8. The Galapagos annealing interface for The results of trial values after 1000 continuous trial, 951 of trial is equal 2 .Galapagos Species Record after 26 hours simulation.

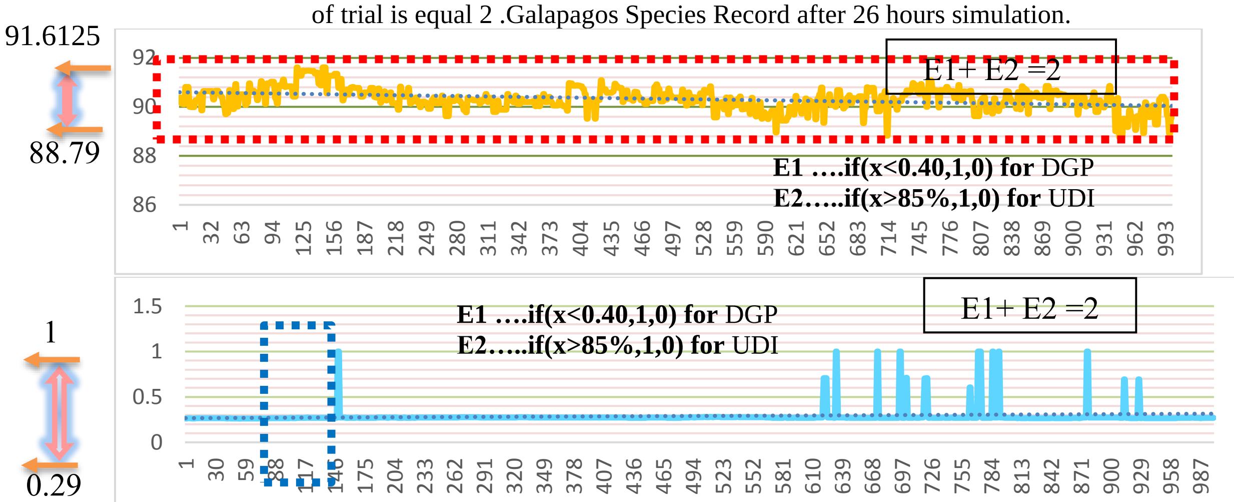

Figure 9. Optimization results for according to UDI and DGP metrics

The results of UDI values after 1000 trial, 802 of trial is more than 90% (according leed 4 point3) ,1000 of trial is more than 85% min is 88.79, max is 91.6125, average is 90.321,The best value is 0.27 for DGP with 91.672 %for UDI .The results of DGP values after 1000 continuous trial , 966 of trial is less than 40%,min is 0.2608, max is 1, average is 0.2904

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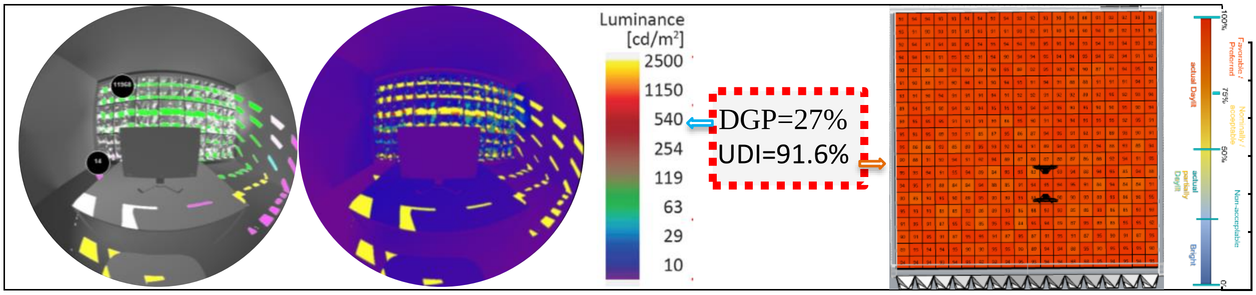
Table 2.The Best result of UDI & DGP for Wavy pattern screen controlled by sin curve attractor in Dec.



For UDI: simulation results were ordered from the optimized performance to the worst ones. the optimized performance achieved Average 91.61% ,66.693% daylit area in deepest space, with 29.037% of partially-daylit and 2.51% over lit areas.

wavy pattern with (open percentage for zone A min =45%, max=70%, for zone B min =50%,max=50% and for zone C min =40%,max=45%): reached the acceptance DGP of 27% which in Imperceptible zone ,it shows a slight potential for more improvement than other case (point attractor in December),Samples of the most unique of these configurations are illustrated in table 5.

Part two:

The results of UDI & DGP for pattern screen controlled by Point attractor in June & December.

- **firstly:** The results will be displayed of Galapagos annealing for 1000 continuous trial.
- **secondly:** The results of 1000 continuous trial will be analyzed in charts by excel program.
- **thirdly:** The best results will be displayed.

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A-The results of UDI & DGP for pattern screen controlled by point attractor in June.

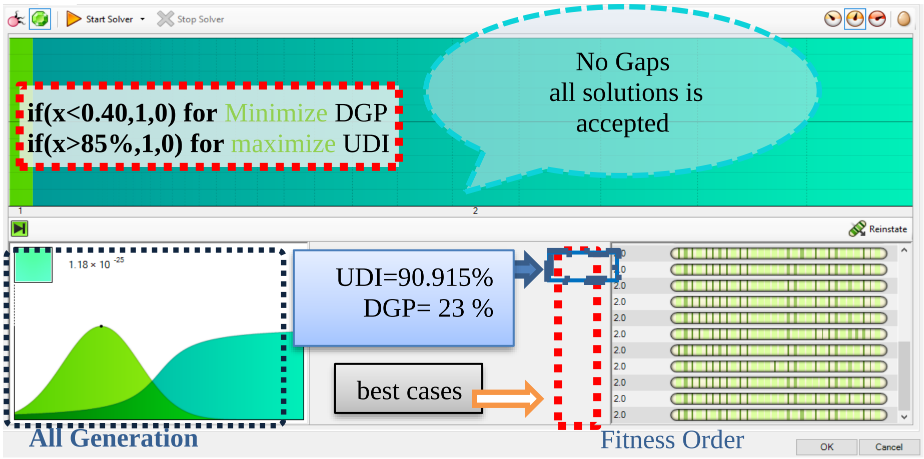

Figure 10. The results of trials values after 1000 trial, all of trial is equal 2 Galapagos Species Record after 34 hours simulation

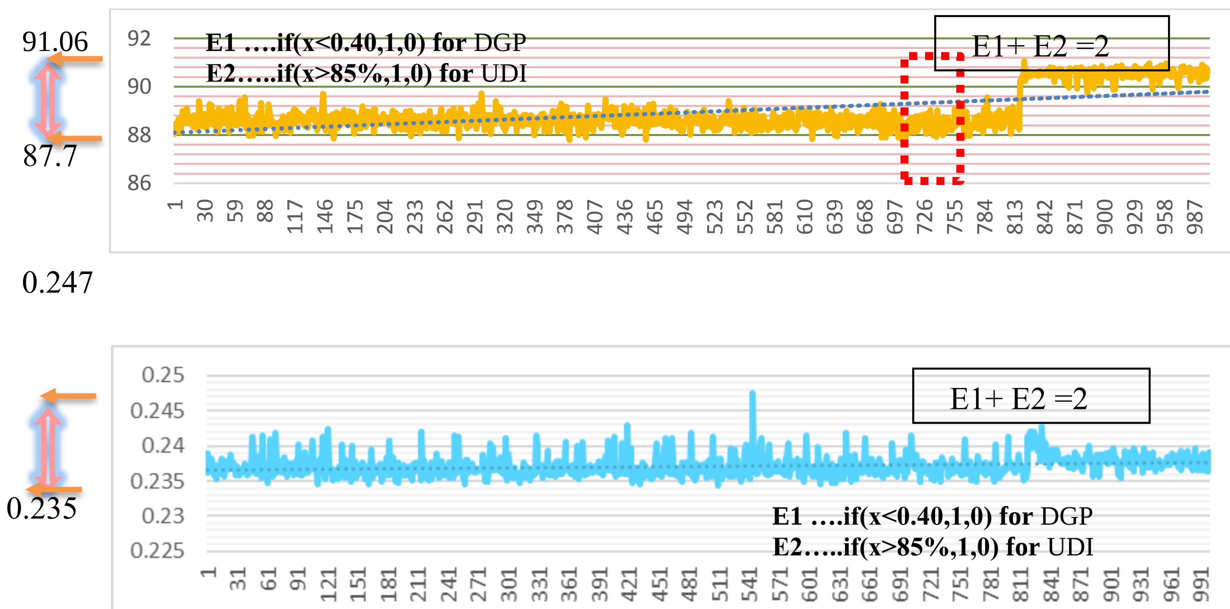

Figure 11. Optimization results for according to UDI and DGP metrics

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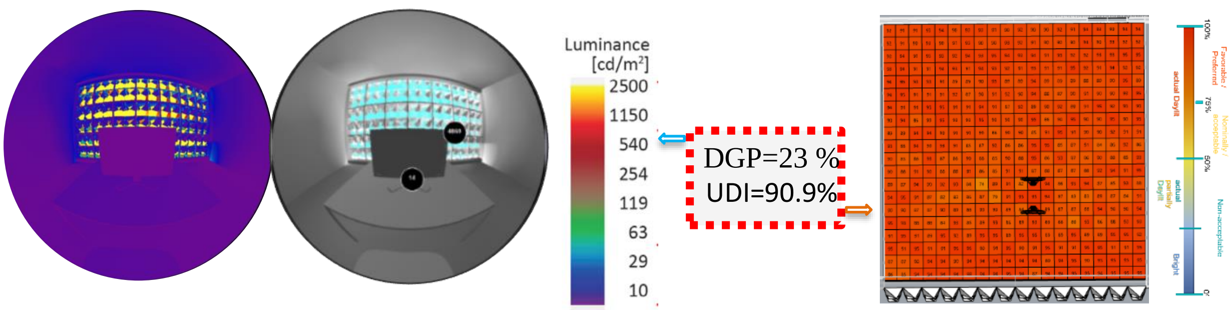
The results of UDI values after 1000 continuous trial, 174 of trial is more than 90% , min is 87.69, max is 91.06, average is 88.942765,The best value is 23% for DGP with 90.915%for UDI .The results of DGP values after 1000 continuous trial, 1000 of trial is less than 40%,24 of trial is less than 23.5%, min is 0.23446, max is 0.247451, average is 0.237153

Table 3.The Best result of UDI & DGP for pattern screen controlled by point attractor in June



For UDI: simulation results were ordered from the optimized performance to the worst ones. the optimized performance achieved Average: 90.915%, 67.4245% daylit area in deepest space, with 24.823% of partially-daylit and 3.4375% over lit areas.

pattern with (open percentage for zone A1 =80%,A2=75%, for zone B1 =55%,B2=54% and for zone C1 =51%,C2=54%): reached the acceptance DGP of 23% which in Imperceptible zone, it shows a slight potential for more improvement than other case(wavy façade). Samples of the most unique of these configurations are illustrated in table 7.

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B-The results of UDI & DGP for pattern screen controlled by point attractor in December.

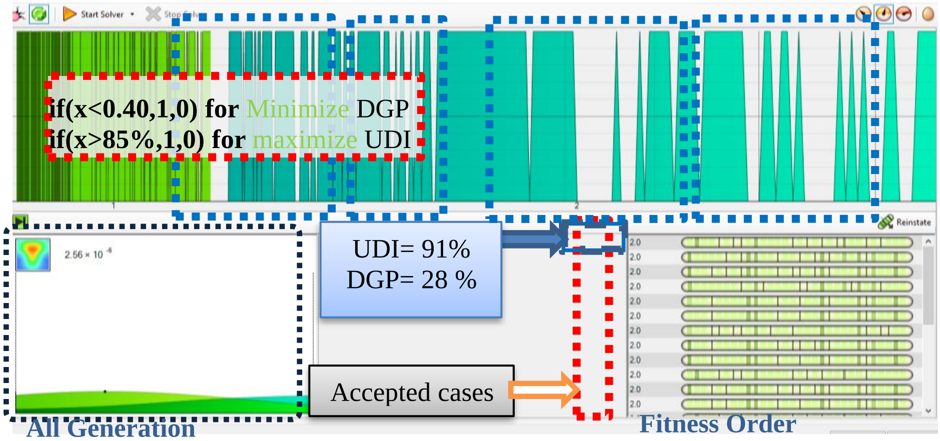

Figure 12.The Galapagos annealing interface ,the results of trials values after 1000 continuous trial, 779 of trial is equal 2 Galapagos Species Record after 3 4hours simulation.

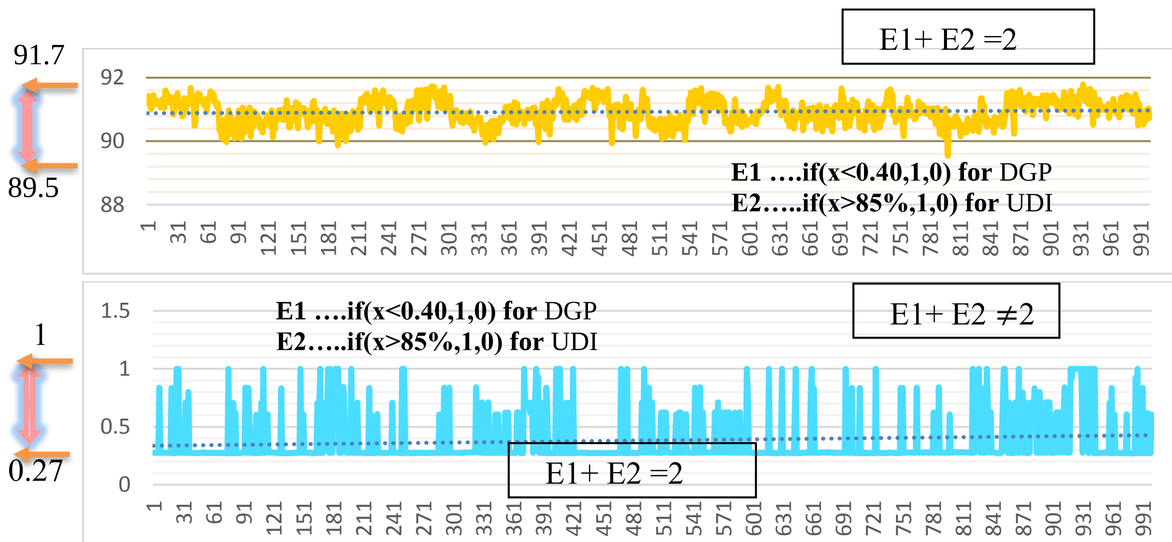

Figure 13. Optimization results for according to UDI and DGP metrics

The results of UDI values after 1000 continuous trial , 992 of trial is more than 90% 575 of trial is less than 91%, min is 89.54, max is 91.7875, average is 90.9246875,The best value is 0.272259 for DGP with 91.09 for UDI .The results of DGP values 789 of trial is over than 40%, min is 0.270568, max is1, average is 90.92

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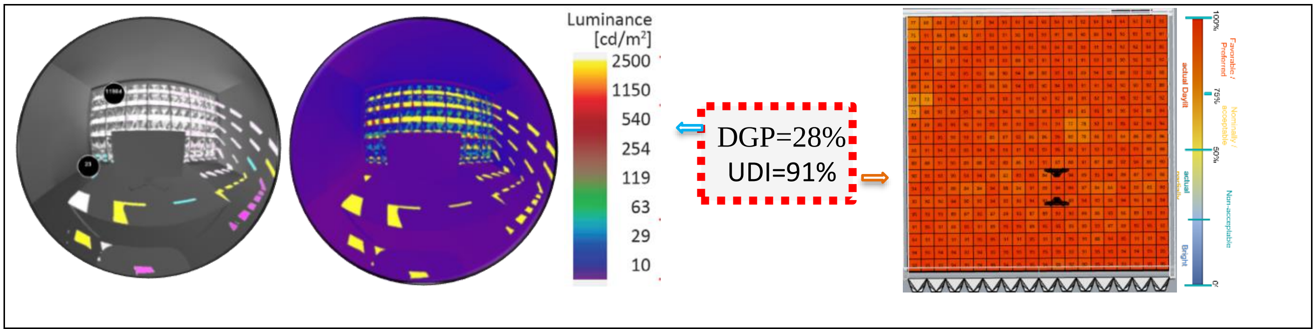
Table 4. The Best result of UDI & DGP for pattern screen controlled by point attractor in Dec.



For UDI: simulation results were ordered from the optimized performance to the worst ones. the optimized performance achieved Average: 91.09%,66.283% daylit area in deepest space, with 28.852% of partially-daylit and 2.365% over lit areas. Samples of the most unique of these configurations are illustrated in table 8.

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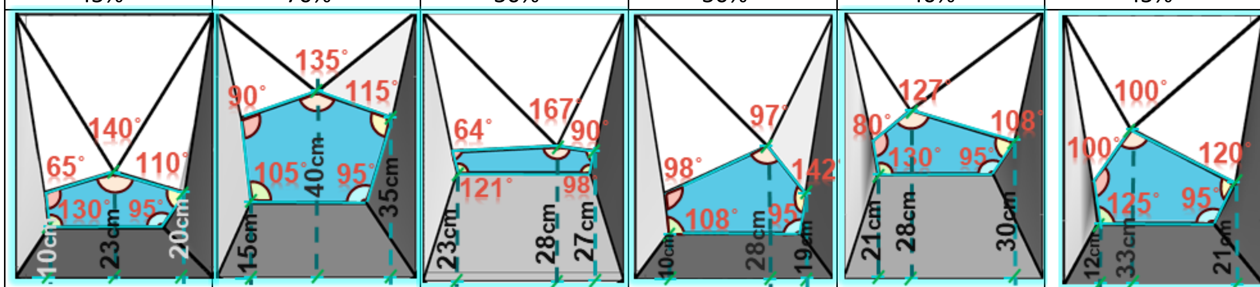
Table 5, the wavy adaptive facade responding to sunlight, shows the different deflection curves of the adaptive model in December.

Zone		A		B		C		Front view
		min	max	min	max	min	max	
		45%	70%	50%	50%	40%	45%	
Daylight Parameters								
UDI	91.612%							
DGP	27%							
Point A,B	Angle	A=130˚,B=95 ˚	A=105˚,B=95 ˚	A=121˚,B=98 ˚	A=108˚,B=95 ˚	A=130˚,B=95 ˚	A=125˚,B=95 ˚	
	Amplitude A	X=7 ,Y=10cm	X=7 ,Y=15cm	X=7 ,Y=23cm	X=7 ,Y=10cm	X=7 ,Y=21cm	X=7 ,Y=12cm	
	Amplitude B	x=30cm	x=35cm	x=35cm	x=35cm	x=32cm	x=32cm	
Point D	Angle	140˚	135 ˚	167˚	97 ˚	127 ˚	100˚	
	Amplitude	X=20 ,Y=23cm	X=20 ,Y=40cm	X=28 ,Y=28cm	X=28 ,Y=28cm	X=14 ,Y=36cm	X=14 ,Y=33cm	
Point C,E	Angle	C=110˚,E=65 ˚	C=115 ˚,E=90 ˚	C=90 ˚,E=64 ˚	C=142 ˚,E=98 ˚	C=108 ˚,E=80 ˚	C=120 ˚,E=100 ˚	
	Amplitude C	X=35 ,Y=20cm	X=37 ,Y=35cm	X=35 ,Y=27cm	X=36 ,Y=19cm	X=36,Y=30cm	X=37 ,Y=21cm	
	Amplitude E	x=6cm	x=5cm	x=6cm	x=6cm	x=6cm	x=6cm	
	Depth(Z)	25cm		20cm		25cm		
Crv Points		Pt 1	Pt 2	Pt 1	Pt 2	Pt 1	Pt 2	
parameterizes		X=0.15,Y=0.15	X=0.56,Y=0.95	X=0.15,Y=0.15	X=0.56,Y=0.95	X=0.15,Y=0.15	X=0.56,Y=0.95	

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	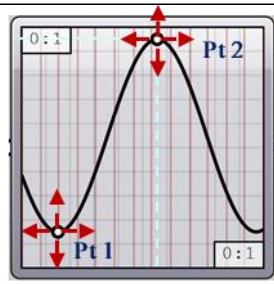	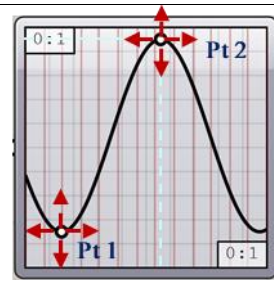	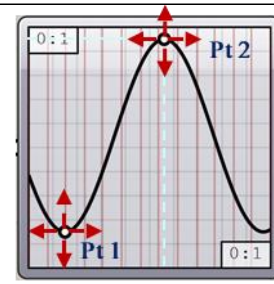	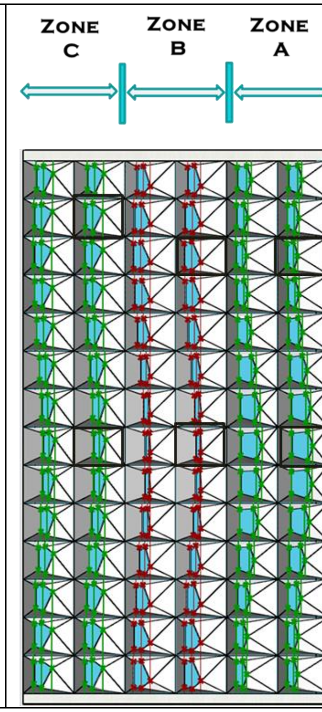

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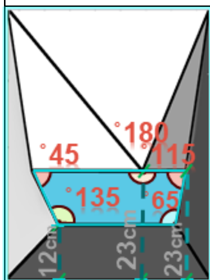
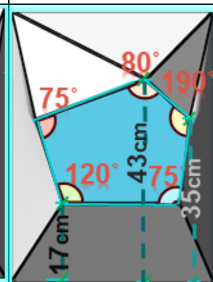
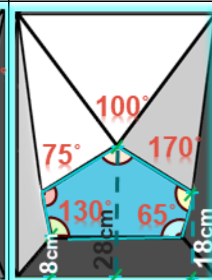
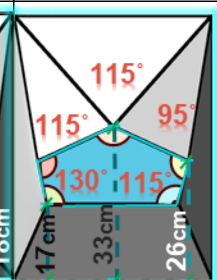
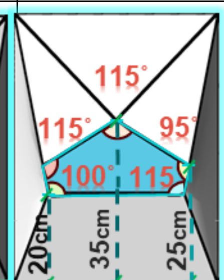
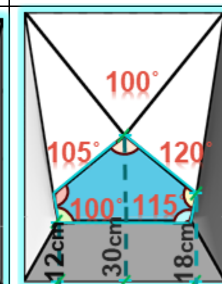
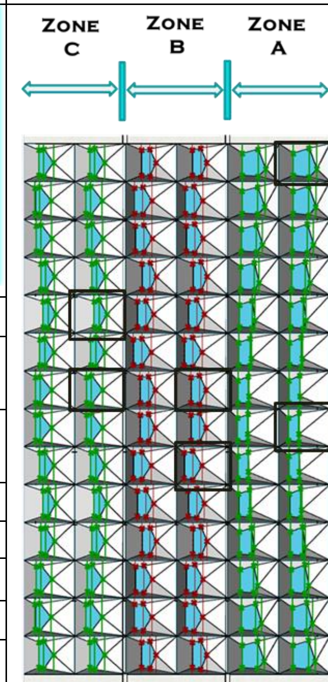
Table 6, the wavy adaptive facade responding to sunlight, shows the different deflection curves of the adaptive model in June.

Zone		A		B		C		
		min	max	min	max	min	max	
		40%	60%	20%	45%	40%	50%	
Daylight Parameters UDI 89.71% DGP 24%								
Point A,B	Angle	A=135˚,B=65 ˚	A=120˚,B=75 ˚	A=130˚,B=65 ˚	A=130˚,B=115	A=100˚,B=115	A=100˚,B=115	
	Amplitude A	X=11 ,Y=12cm	X=11 ,Y=17cm	X=7 ,Y=8cm	X=7 ,Y=17cm	X=7 ,Y=20cm	X=7 ,Y=12cm	
	Amplitude B	x=36cm	x=36cm	x=35cm	x=36cm	x=36cm	x=36cm	
Point D	Angle	180˚	80˚	100˚	115˚	115˚	100˚	
	Amplitude	X=28 ,Y=23cm	X=30 ,Y=43cm	X=21 ,Y=28cm	X=22 ,Y=33cm	X=22 ,Y=35cm	X=21 ,Y=30cm	
Point C,E	Angle	C=115˚,E=45 ˚	C=190˚,E=75 ˚	C=170˚,E=75 ˚	C=95˚,E=115 ˚	C=95˚,E=115 ˚	C=120˚,E=105 ˚	
	AmplitudeC	X=37 ,Y=23cm	X=38 ,Y=35cm	X=37 ,Y=18cm	X=38 ,Y=26cm	X=37 ,Y=25cm	X=37 ,Y=18cm	
	Amplitude E	x=5cm	x=5cm	x=5cm	x=5cm	x=6cm	x=6cm	
	Depth(Z)	30cm		30cm		15cm		
Crv Points		Pt 1	Pt 2	Pt 1	Pt 2	Pt 1	Pt 2	
parameterizes		X=0,Y=0.69	X=0.55,Y=0.3	X=0.11,Y=0.16	X=0.24,Y=0.55	X=0.30,Y=0.56	X=0.50,Y=0.40	

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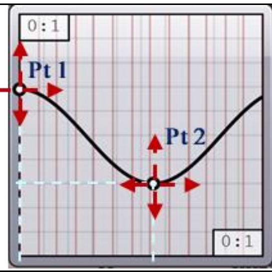
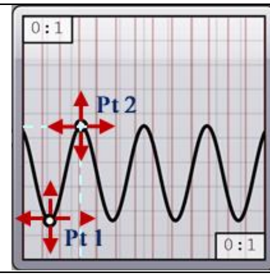
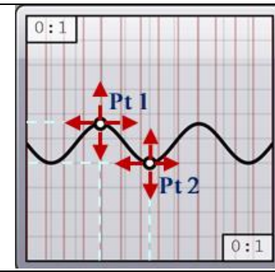
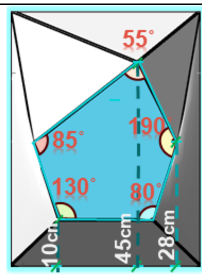
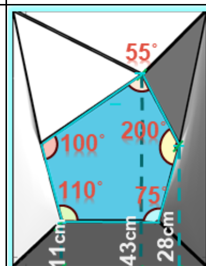
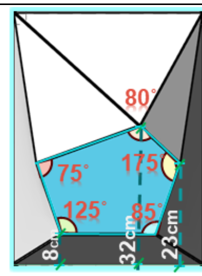
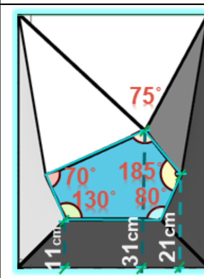
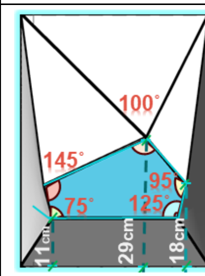
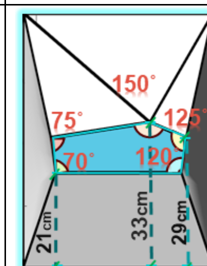
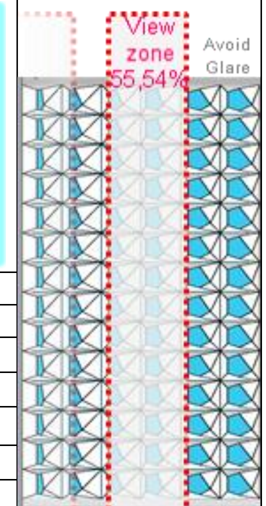
				

Table 7.point attractor in June, Table 8. .point attractor in December								
zone		A1	A2	B1	B2	C1	C2	
UDI 90.915% DGP 23%								
Point A,B	Angle	A=130˚,B=80 ˚	A=110˚,B=75 ˚	A=125˚,B=85 ˚	A=130˚,B=80 ˚	A=75˚,B=125˚	A=70˚,B=120˚	
	Amplitude A	X=10 ,Y=10cm	X=11 ,Y=11cm	X=11 ,Y=8cm	X=11 ,Y=11cm	X=7 ,Y=11cm	X=7 ,Y=21cm	
	Amplitude B	x=32cm	x=32cm	x=32cm	x=32cm	x=35cm	x=35cm	
Point D	Angle	55˚	55˚	80˚	75˚	100˚	150˚	
	Amplitude	X=28 ,Y=45cm	X=29 ,Y=43cm	X=28 ,Y=32cm	X=28 ,Y=31cm	X=28 ,Y=29cm	X=28 ,Y=33cm	
Point C,E	Angle	C=190˚,E= 85˚	C=200˚,E= 100˚	C=175˚,E=75 ˚	C=185˚,E=70 ˚	C=95˚,E=145 ˚	C=125˚,E=75 ˚	
	AmplitudeC	X=37 ,Y=28cm	X=37 ,Y=28cm	X=38 ,Y=23cm	X=37 ,Y=21cm	X=38 ,Y=18cm	X=37 ,Y=29cm	
	AmplitudeE	x=5cm	x=6cm	x=5cm	x=6cm	x=5cm	x=6cm	

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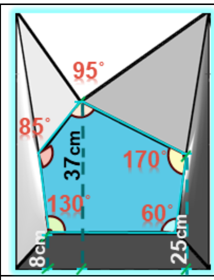
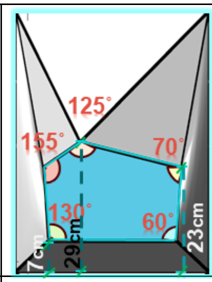
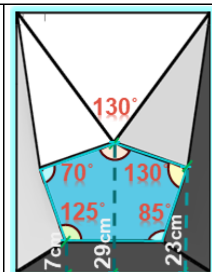
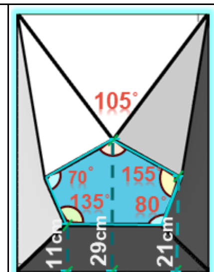
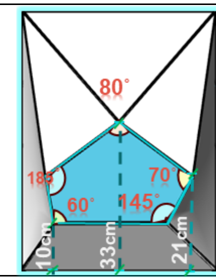
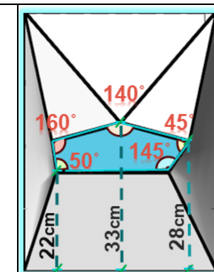
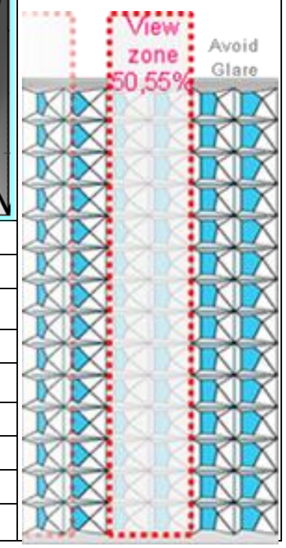
UDI 91% DGP 28%								
Point A,B	Angle	A=130˚,B=60 ˚	A=130˚,B= 60˚	A=125˚,B=85 ˚	A=135˚,B=80 ˚	A=60˚,B=145˚	A=50˚,B=145˚	
	Amplitude A	X=7 ,Y=8cm	X=7 ,Y=7cm	X=11 ,Y=7cm	X=11 ,Y=11cm	X=7,Y=10cm	X= 7,Y=22cm	
	Amplitude B	x=36cm	x=36cm	x=32cm	x=32cm	x=32cm	x=32cm	
Point D	Angle	95˚	125˚	130˚	105˚	80˚	140˚	
	Amplitude	X=15 ,Y=37cm	X=15 ,Y=29cm	X=22 ,Y=29cm	X=21 ,Y=29cm	X=2 1,Y=33cm	X=2 2,Y=33cm	
Point C,E	Angle	C=170˚,E=85 ˚	C=155˚,E=70 ˚	C=130˚,E=70 ˚	C=155˚,E=70 ˚	C=70,E=185 ˚	C=45˚,E=160 ˚	
	Amplitude C	X=38 ,Y=25cm	X=37 ,Y=23cm	X=38 ,Y=23cm	X=37 ,Y=21cm	X=3 8,Y=21cm	X=37 ,Y=28cm	
	Amplitude E	x=5cm	x=6cm	x=5cm	x=6cm	x=5cm	x=6cm	
	Depth (Z)	25cm		30cm		20cm		

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Competing Interests

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

Conclusion:

This paper presented a simulation-based study for an adaptive solar screen design driven by daylight and glare performance. It was based on the integration of the performance simulation tool with the parametric design approach and the Genetic Algorithms method using DIVA, Grasshopper and Galapagos respectively.

The use of the optimization method proposed in this study succeeded in providing a comprehensive range of design variations. This allowed for confirming the effectiveness of using the proposed parametric approach in identifying a considerable number of unconventional designs that maintain maximum daylighting performance. The genetic algorithm adopted in this study enhanced daylighting performance during the optimization process gradually through 50 Generations, by which the specific objective was set to maximize daylit area percentage and to minimize the over-lit and partially daylit area percentages. In the last generation, by the end of the optimization process, optimum solutions were typically defined. These all fulfilled the targeted criteria.

From the previous analysis, the monthly simulation was determined by the optimal screen configurations for each month;

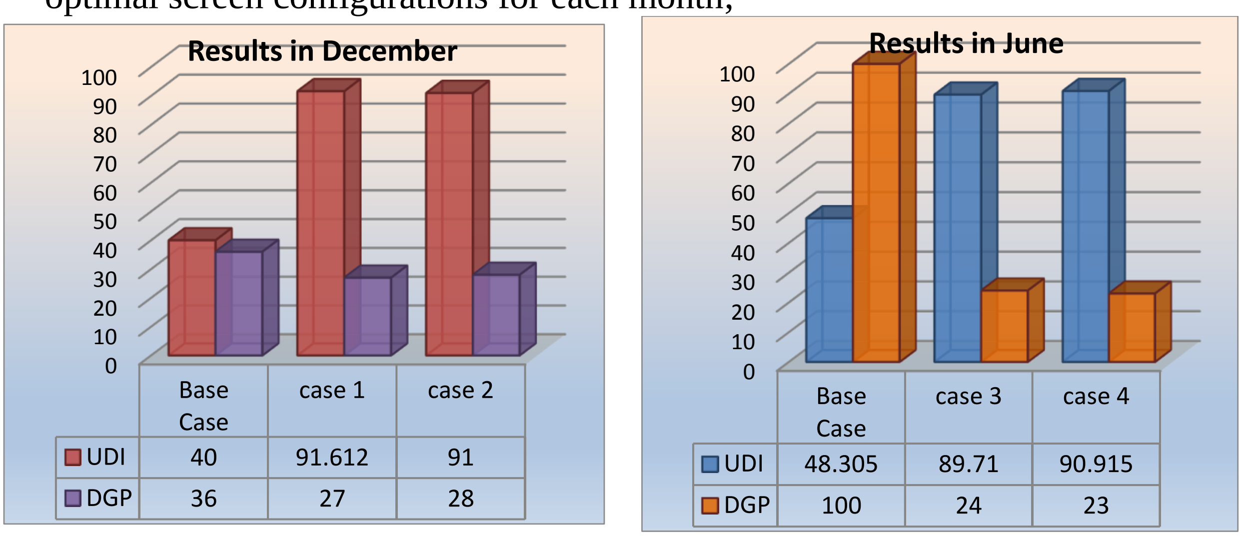

Figure14.Comparing percentage simulations for UDI and DGP for the best result from 1000 continuous trial by Galapagos for curve attractor (Source: The Researcher).

Case 1: Wavy pattern screen controlled by sin curve attractor in December as shown in table 5.
Case 2: pattern screen controlled by point attractor in December as shown in table 8.
case 3: Wavy pattern screen controlled by sin curve attractor in June as shown in table 6.
Case 4: pattern screen controlled by point attractor in June as shown in table7.
for month 6, the monthly simulations for both UDI, DGP for the adaptive pattern in Galapagos annealing using Gecko Plugin For sun-tracking system by pattern screen controlled, the values of the parameters as shown in Tables, point attractor was the optimal case for this month for balancing daylighting and glare performance. the UDI is 90.915 % which is more than 50%, there is a slight to improve the light condition Compared to the wavy façade which controlled by curve attractor, and the glare remains as Imperceptible DGP is 23%.

- **for month 12**, the monthly simulations for both UDI, DGP for the adaptive pattern in Galapagos annealing using Gecko Plugin For sun-tracking by attractor system, the values of the parameters, wavy façade was the optimal case for this month for balancing daylighting and glare performance. the UDI is 91.612 % which is more than 50%, there is a marginal improvement the light condition Compared to the point attractor; shows a slightly good light condition and the glare remains as Imperceptible DGP is 27%.

Ultimately, the use of the Galapagos annealing in this paper succeeded in giving good results with close improvements.

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