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Parametric Approach for Multi-Objective Optimization for Daylighting and Energy Consumption in Early Stage Design of Office Tower in New Administrative Capital City of Egypt

Ahmed Mohamed Yousef Toutou[1]

[1] *Master Student in Alexandria University, B.Sc. Mansoura University*

Abstract

In the last few years, great improvements have been achieved in building optimization methods. Mustapha Sadeghipour Roudasri and others found new tools " Ladybug, Honeybee and Butterfly" which could gather many simulation engines and visualization tools " Energyplus, OpenStudio, Radiance, Daysim, CFD, OpenFOAM, etc ". Consequently, These simulation engines will integrate with parametric modeling in Grasshopper and multi-objective optimization through Octopus plug-in to form an early stage parametric optimization framework in one canvas. This paper aims at finding the suitable plane shape and building configurations for multi-objective optimization to the daylighting levels and energy consumption of office tower building in the new administrative capital city in Egypt through parametric based optimization method. One of the most commonly used plan shapes of these types of buildings was studied. This shape and many building configurations "WWR, window material, wall material and shading devices" were parametrically modeled. These Parameters will form many tradeoffs which will be simulated and optimized by the previous framework. Spatial Daylight Autonomy "SDA300/50%" is examined to optimize Daylighting while Energy Use Intensity " EUI" is used for energy consumption optimization. Multi-Objective Optimization was performed by genetic algorithms via Octopus plug-in. The near optimum design for plan shape and building configuration to balance between daylighting and energy consumption is achieved and will be a reference model for office tower buildings in this zone in Egypt which is under rapid development. The framework used in this study will guide designers to find effective solutions for early-stage design of office building in one canvas without any conflict between several engines and scripts.

Keywords

Parametric Optimization; Genetic Algorithm; Daylighting; Energy Simulation; Early Stage Design

1. Introduction

The new administrative capital of Egypt is planned to situate 45 km east of Cairo city on 700 total area to relive congestion in Cairo and to help to strengthen and diversify the country's economic potential by creating new places to live, work and visit. (SIS, 2017) Because of the huge numbers of office buildings which will be constructed in administration and business district in addition to the energy crisis in Egypt, A reference office building model will be designed to be a guideline for deigning this type of buildings and the whole building optimization framework will be valuable steps to follow in another different types. A parametric multi objectives' optimization framework will be held using genetic algorithms to the rectangular office building shape to find the optimum design. Parametric modeling helped to automatic change in shape parameters to form various alternatives which will be the domain for solutions. Daylighting and energy will be the objectives of optimizations process while SDA and EUI will be the metrics. Many shape parameters in addition to WWR, a glass material, wall construction and shading devices will control the early stage design of this building.

Nomenclature

A. SDA : Spatial Daylight Autonomy

B. EUI : Energy Use Intensity

C. GA : Genetic Algorithms

D. MOO: Multi-Objective Optimization

2. Literature Review

Optimization always pointing to find the best case of something ”design or system” whether in function or efficiency as possible. (Nguyen et al., 2014) Optimization on performance objectives assists designers to automate a large pool of design trade-offs and direct the design to perform efficiently. (Østergård et al., 2016). Parametric modeling was integrated with optimization techniques to introduce an intelligent searching method for efficient feedback. (Lin & Gerber, 2014)This approach can be used to enhance the performance of buildings as building parameters are varied to see its influence on the objectives of design. The computer building model is usually solved by construct infinite sequence of progressively better approximations. The optimum solution will be found in the search space. (Nguyen et al., 2014) However parametric analysis is an old idea, the availability of automation and software has facilitated it to be pursued. (Konis et al., 2016) Building optimization started many years ago. Building performance simulation contributed to significant progress in building optimization in early-stage design especially when there is an integration with parametric design and genetic algorithms. (Roudsari et al., 2013) paved the way for this integration when they had designed a new Grasshopper Toolkit ”Ladybug, Honeybee, Butterfly, and Dragonfly”. This toolkit is using grasshopper canvas while introducing daylighting, energy and wind simulation. Radiance and Daysim are used for daylighting simulation and Energy-plus and OpenStudioare are used for energy simulation while OpenFOAM and CFD are used for wind simulation. Octopus plugin accomplished the missing ring of optimization framework in which parametric design, building performance simulation, and genetic algorithms are integrated to perform multi-objective optimization. (Konis et al., 2016) proposed this framework before and called it passive performance optimization framework ”PPOF”. This research achieved significant results in daylighting and energy performance while spatial useful daylighting illumination ”SUDI” has a dramatic increase ranging from 27% to 65%in the best cases and energy use intensity ”EUI” has a considerable decrease ranging from 4% to 7% depending on the local site and climatic conditions. (Konis et al., 2016)

This framework and many others which depend on the same idea of exploiting the integration of parametric modeling, building performance simulation and genetic algorithms to design the whole building or specific parts. some researchers designed shading louvers such as (Wagdy & Fathy, 2015) which used Grasshopper and Diva plugin to find the optimum daylighting performance shading device combination for classroom in Cairo desert while some others designed skylights, such as (Turrin, et al., 2012) which used ParaGen in parametric modeling and used genetic algorithms in large roof structure optimization. In addition, some researchers optimized the building massing such as (Suyoto, et al., 2015) which utilized Grasshopper to find the most shaded and comfortable outdoor area while others optimized fenestrations and windows designs like (El Daly, 2014) which employs Grasshopper to generate different fenestrations systems and (Qingsong & Fukuda, 2016) who find the most suitable WWR in an office building using Grasshopper in parametric modeling, Ladybug and Honeybee in BPS and Galapagos as Genetic algorithms operator. As well, Facade design was optimized by many researchers like (Elghazi, et al., 2014) who used Kaleido cycle design technique in the residential facade to promote daylighting requirements utilizing Grasshopper and Diva for Parametric modeling and daylighting simulation respectively.

3. Methodology

The multi-objectives framework used in this research consists of three main parts: parametric modeling, building performance simulation, and genetic algorithms. These three parts are forming closed loop cycle which begins with modeling the building parametrically, then evaluate the building performance resulting from specific parameters. In turn, the genetic algorithms guide design parameters to satisfy optimization objectives through ” survival of the fittest ” role. After that, the new alternative is formed and the cycle is repeated again and again. The Pareto front which represents all alternatives in one single chart will be studied and the optimum solutions will be found through objective function. The closed-loop cycle is applied in Grasshopper software canvas which will be responsible for parametric modeling of the building. In turn, the responsibility for building performance simulation part is for Ladybug and Honeybee plugins. These are free and open source environmental plugin for Grasshopper3D which provide energy and daylighting modeling by using validated simulation engines such as EnergyPlus, OpenStudio, Radiance, and Daysim. (Roudsari et al., 2013) Finally, the genetic algorithms part is performed via Octopus which is a Grasshopper plugin for applying evolutionary principles to parametric design and problem-solving. It allows the search for many goals at once, producing a range of optimized trade-off solutions between the extremes of each goal.(Vierlinger, et al., 2013)

Assume that, a twelve levels office building is supposed to be designed in the new administrative capital of Egypt. The common shape of a rectangular office building with the inner core is used. The building core is a 36 m2 area stairs and elevators are set while the outer zone is an open office space. The length and width of this tower building are supposed to be varied between 40 m and 50 m while this rectangular plan shape is subjected to some parametric variations to find more energy and daylighting efficient plan design.

3.1. Parametric modeling

In this subsection, the parametric modeling of floor shape design, window creation, exterior shading devices and surrounding context will be clarified.

A. Floor shape

The building floor shape is supposed to be designed as rectangle shape which has parametric length and width (X and Y). These two parameters are supposed to be an integer number between (40m and 50m). The four sides of the rectangle are divided from the center to form 4 points which will be the center s of four squares. The side length of this square is set to be a parametric integer value from (2m to 10m). The rotation angle of this square is set to be valued from (0° to 75° with 15° increment). These four squares are subtracted from the original rectangle floor shape as seen in Figure 1. At the center of the original rectangle floor shape, there is square shaped core with 36 m2 area. The floor layout shape could be more complex by editing more subtractions or additions to it which will be applied in another research.

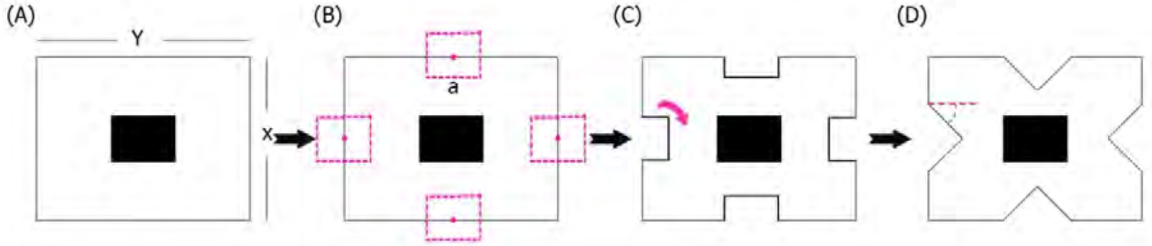


Figure 1. Conceptual Idea of Plan Shape Optimization.

B. Windows

The windows are created parametrically based on the window to wall ratio ”WWR”. Every facade has a specific WWR varied from 0.1 to 0.9 with 0.1 increments.WWR is an important factor which will affect significantly on the balance between daylighting and energy performance. So, WWR values of the four facades are isolated to reach the optimum value for everyone.

C. Exterior shading devices

The system of shading devices is set to be simple shading louvers which will be vertically in the south facade and horizontal in the east and west ones. As there is no direct sun exposure in the north, there aren't any shading louvers in the north facade. Louvers count, depth and rotation will be three factors which will control the parametric form of shading devices. Louvers count will vary between 2 and 10 with 2 increments while louvers depth will vary between 0.05m and 0.5m with 0.05 increment. As well, rotation angle will be from -75° to 75° with 15° increment.

D. Surrounding context

A virtual surrounding context is set to depend on the urban planning of the new city. Essential note should be remarked that the results may be varied significantly when the surrounding context differs.

Table 1. Building Parameters Adjusted During Optimization Process. (By Researcher)

Building Parameters			Attributes	Values
Geometry	Building length (X)		(40-50m with an increment of 1m)	11
	Building width (Y)		(40-50m with an increment of 1m)	11
	Subtract square side (a)		(2-8m with an increment of 1m)	7
	Subtract square angle (α)		(0°-75° with an increment of 15°)	6
	WWR	North (WWR_N)	(0.1-0.9 with an increment of 0.1)	9
		South (WWR_S)	(0.1-0.9 with an increment of 0.1)	9
		East (WWR_E)	(0.1-0.9 with an increment of 0.1)	9
		West (WWR_W)	(0.1-0.9 with an increment of 0.1)	9
Materials	Wall construction (WC)		5 varied wall constructions mentioned in 00000000	5
	Glass materials (GM)		10 varied glass materials mentioned in 00000000	10
Shading Devices	Count	South (C_S)	(2-10 with an increment of 2)	5
		East&West(C_{EW})	(2-10 with an increment of 2)	5
	Rotation angle	South (θ_S)	(-75°-75° with an increment of 15°)	11
		East&West (θ_{EW})	(-75°-75° with an increment of 15°)	11
	Depth	South (D_S)	(0.05-0.5m with an increment of .05m)	10
		East&West (D_{EW})	(0.05-0.5m with an increment of .05m)	10

3.2. Building performance simulation

A. Weather data file

The used weather data file in this research is at Cairo international airport which locates approximately in the same latitude 30°. This is because there is not a specified weather data file for the new administrative capital of Egypt.

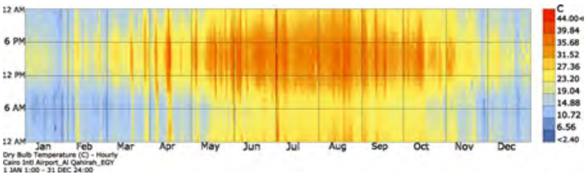


Figure 2. DryBulb Temperature of 6th of October City. (By Researcher Using Ladybug)

B. Energy simulation

The main purpose of energy simulation is finding energy use intensity ”EUI” metric which represents the energy consumed during the year per unit area which need to be minimized through optimization framework. ”EUI” is measured by J/m2. The energy simulation in Ladybug and Honeybeerun through several steps in which many factors should be specified. Cooling and heating set point which controls the running of HVAC system is set to be 24° and 20° respectively. The HVAC system is set to be VAV w/PEP Boxes. The number of people per floor area, lighting density per floor area and equipment load per floor area are designed as 0.0538 ppl/m2, 8.8264 w/m2 and 8.07 w/m2 respectively These values are referenced from ASHRAE base case model for a medium office building in Phoenix region 2013. For EnergyPlus materials, there are two main elements which affect dramatically on the energy performance of the building. First, wall construction material which will be five materials compositions from the Egyptian local market. These materials have different compositions which lead to different conductivity and U value as seen in Table 2. Second, glass materials which have the most effective impact on both daylighting and energy performance. Ten glass compositions shown in Table 3 were set to find the most suitable the performance balance. These glass compositions were constructed in Window 7.5 software which designed by Lawrance Barkely National lab, then they were exported to Ladybug and Honeybee.

Table 2. Used Building Construction Materials Composition.

	Single Red Brick	Double Red Brick	Egypt Cement Hollow Brick	Egypt Cement Bulk Brick	Double red brick wall air gap	Double red brick wall with isolation
Layer 1	Egyptian Plaster (5mm)	Egyptian Plaster (5mm)	Egyptian Plaster (5mm)	Egyptian Plaster (5mm)	Egyptian Plaster (5 mm)	Egyptian Plaster (5 mm)
Layer 2	Portland Cement Mortar (25mm)	Portland Cement Mortar (25mm)	Portland Cement Mortar (25mm)	Portland Cement Mortar (25mm)	Portland cement mortar (25 mm)	Portland cement mortar (25 mm)
Layer 3	Egyptian Red Brick (100mm)	Egyptian Red Brick (200mm)	Cement Hollow Brick (200mm)	Cement Bulk Brick (200mm)	Egyptian red brick (100 mm)	Egyptian red brick (100 mm)
Layer 4	Portland Cement Mortar (25 mm)	Portland Cement Mortar (25mm)	Portland Cement Mortar (25mm)	Portland Cement Mortar (25mm)	Air gap	Egyptian Glass Wool (5 mm)
Layer 5	Egyptian Plaster (5 mm)	Egyptian Plaster (5 mm)	Egyptian Plaster (5 mm)	Egyptian Plaster (5 mm)	Egyptian red brick (100 mm)	Egyptian red brick (100 mm)
Layer 6	-	-	-	-	Portland cement mortar (25 mm)	Portland cement mortar (25 mm)
Layer 7	-	-	-	-	Egyptian Plaster	Egyptian Plaster (5 mm)

C. Daylighting simulation

Spatial daylighting illumination ”SDA300/50%” is a daylighting metric which represent s the percentage of floor area having 300 lux of illumination for at least 50% of the occupied hours from (8 am-6 pm) throughout the year.(Wagdy & Fathy, 2015) The preferred value for SDA is 75% based on previous publications for Illuminating Engineering Society ”IES”. According to (USGBC, 2013), the analysis grid of daylighting illumination is set to 0.76m above the floor finishing while grid has 3 square meter size. For Radiance materials, The same optical, transmittance and reflectance properties of EnergyPlus glass materials were converted to Radiance materials and set to daylighting model. Walls, roof, and ground materials are set to off-white plaster, white paint and gray tiles (30cm * 30cm) respectively which dealt as neutral materials for all daylighting simulation alternatives.

Table 3. The Layers of Used Glas Materials.

	Layer 1	Th	Layer 2	Th	Layer3		Layer4	Th	Layer5	Th
Single Clear	Clear Glass	3.05	-	-	-	-	-	-	-	-
Double Clear Argon	Clear Glass	3.05	Argon	12.7	Clear Glass	3.05	-	-	-	-
Double Low-E air	Comfort Select R42	3.18	Air	12.7	Clear Glass	3.05	-	-	-	-
Double Clear Air	Clear Glass	5.72	Air	12.0	Clear Glass	5.72	-	-	-	-
Double Low-E Vacuum	LowE 270	4.0	Vacuum	0.1	Clear Glass	3.96	-	-	-	-
Saga Blue	SageGlass_9_Blue_40clr	8.8	Air	12.7	Clear Glass	3.0	-	-	-	-
Saga Blue	SageGlass_9_Green_49clr	8.7	Air	12.7	Clear Glass	3.0	-	-	-	-
Triple Clear	Clear Glass	5.72	Air	12.7	Clear Glass	5.72	Air	12.7	Clear Glass	5.72
Trible-Low-E-Air	LoE270-4	4.0	Air	12.7	Clear Glass	5.72	Air	12.7	Clear Glass	5.72
Trible-Low-E-Argon	LoE270-6	6.0	Argon	12.7	Clear Glass	5.72	Argon	12.7	Clear Glass	5.72

3.3. Genetic algorithms

Genetic algorithms (GAs) or evolutionary algorithms simulate the natural selection and the survival of the fittest which exist in nature to find the optimum solution to the problem. The genetic algorithms begin with calculating random solutions and then addressing all these solutions to the genetic operators. Subsequently, by using the genetic operator’s new solutions are generated from the first solution. The fitness value which mentions how much it fits the solution will index all solutions. This process is used to make the solutions with higher fitness and using the genetic operators to produce new generations. Then, recombination and mutations should be utilized to produce the best solutions generated or chose from the existing potential solutions. This process carries on forever until a convenient solution is found.(Musleh, 2012) Octopus plugin will perform this operation to find the optimum design. The production of following generations and finding the optimum solution depends on several setting which will be clarified in Table 4.

Table 4. Genetic Settings in Octopus. (By Researcher)

Elitism	Mutation Probability	Mutation Rate	Crossover Rate	Population Size	Max Generation	Max Eval. Time
0.5	0.1	0.5	0.8	50	50	None

4. Results and Discussion

4.1. Objective Function

The following fitness function was used before by (Konis et al., 2016) to accurately find the optimum solution in Pareto front while EUI and SUDI were the objectives of this study:

$$y = (sUDI_i - sUDI_{min})\, C_1 + -1(EUI_i - EUI_{min})C_2$$

Where: i= result of iteration, min= minimum value of optimization set and max= maximum value of optimization set

$$C_1 = \frac{100}{sUDI_{max} - sUDI_{min}}\ , C_2 = \frac{100}{EUI_{max} - EUI_{min}}$$

The values of fitness function were calculated for some solutions of the optimal Pareto front curve which represent varied cases of the performance of day lighting and energy.

4.2. Pareto front

”Pareto ranking refers to a solution surface in a multi-dimensional solution space formed by multiple criteria representing the objectives”. The Pareto front is often used to explain the optimization results. (Konis et al., 2016) To reach to the Pareto front which is qualified to be analyzed, there are many generations of genomes (Solutions) should be generated. During this research, seven generations were produced, every generation contains 50 genomes. However, the Pareto front chart depends on the values of SDA and EUI, there are many solutions in the elder generations had been vanished as they couldn’t develop properly.

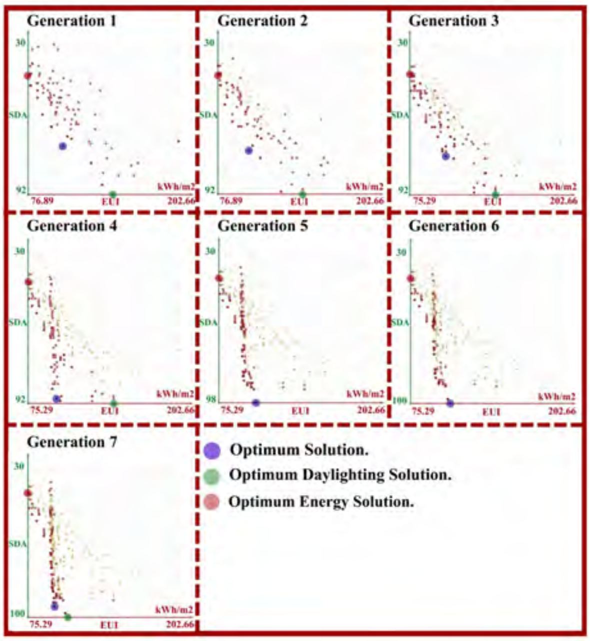


Figure 3. Genomes Generations Produced in Octopus. (By Researcher)

As seen in Figure 3, there is a great improvement in every generation compared to the previous ones. This improvement could be in the objective in the objective function value of the optimum solution as its value is 36.1 in the first generation while it is about 75.4 in the last generation. The objective function values for the optimum solution for the seven generations are 36.1, 41.3, 41.8, 66.8, 72.4, 73.6 respectively. while investigating these results, there are two remarkable improvements in these results. Firstly, the gained achievement in the second generation by 14.4% compared to the first one. Secondly, the dramatic improvement in the fourth generation by nearly 60% compared to the third one. The improvement did not occur only for the objective function value but also for the values of SDA and EUI. The maximum value of SDA in the first generation was 92 and it remained stable till the fourth generation, while it risen significantly to 98 in the fifth one. As well, in the sixth generation SDA value increased to hit the highest point by 100. For the min value of EUI, the first generation was 76.89 kWh/m2 and it remained static in the second one. However, it increased slightly during the third generation while it reached to 75.29 kWh/m2, all of the following generations stayed constant at this value.

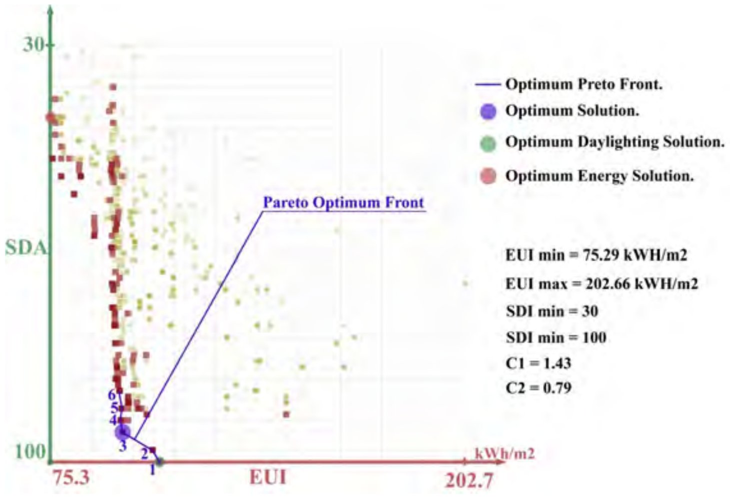


Figure 4. Pareto Front.

Pareto front seen in Figure 4 shows many solutions ”genomes” which are results for different configurations of building parameters. The solutions are referred by dots. Every dot had special color and transparency. Opaque cubes indicate the non-dominated Pareto-front, transparent cubes are dominated solutions still belonging to the Elite. Transparent yellow cubes are elite-solutions from previous generations [history], the more transparent the older. Transparent purple sphere indicates the optimum solution while transparent green and red spheres indicate optimum daylighting and energy solutions respectively. The blue curve represents Pareto optimal front which contains the best solutions for objective function in addition to Pareto optimal solution. The Pareto-optimal solution is, by definition, the best that could be achieved for one objective without disadvantaging at least one other objective.(Baumgartner et al., 2004) The objective function of all solutions of Pareto optimal front is calculated to find Pareto optimal solution. All of these solutions are listed below in Table 5 with all parameters and simulation results.

Table 5. Parameters and Fitness Function Values of Pareto optimum Front Solutions.

	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5	Solution 6
Y	73.54	72.35	75.33	72.98	69.91	65.83
SDA (%)	100	98	95	93	91	88
EUI (kWh/m2)	108.91	106.79	97.59	96.95	97.22	96.59
Length (m)	43	46	43	42	40	43
Width (m)	41	41	49	49	50	49
Subtraction Diameter	10	10	10	10	9	10
Subtraction Angle	15°	15°	75°	75°	75°	75°
WWR North	0.7	0.7	0.7	0.7	0.9	0.7
WWR West	0.8	0.8	0.9	0.8	0.9	0.8
WWR South	0.8	0.8	0.8	0.7	0.7	0.8
WWR East	0.9	0.9	0.9	0.7	0.7	0.9

Continued on next page

Table 5 continued

Glass Material	Double Clear (Argon)	Double Clear (Argon)	Double Low-E (Air)	Double Low-E (Air)	Double Low-E (Air)	Double Low-E (Air)
Wall Construction	Double red brick with Isolation	Double red brick with Isolation	Hollow cement wall	Hollow cement wall	0.2 m red brick wall	0.2 m red brick wall
Ver-Sh.Depth (m)	0.4	0.1	0.05	0.2	0.35	0.2
Ver-Sh.Count	4	12	10	4	2	4
Ver-Sh.Angle	-60°	-60°	45°	0°	-15°	45°
Hor-Sh.Depth (m)	0.1	0.1	0.4	0.4	0.15	0.25
Hor-Sh. Count	6	8	4	4	4	4
Hor-Sh. Angle	60°	60°	-30°	-30°	-30°	-30°

From information listed in Table 5, it is noticed that all subtraction diameters are large and vary between 9m and 10m to allow sun rays penetrating the inner area of an office building and maintain daylighting. As well, WWR of all facades is wide while there is in any facade lower than 0.7. This helped in providing satisfying SDA results in all solutions. The used vertical and horizontal shading devices in east, west, and south encouraged to make WWR larger and larger. Glass material is diverse between double clear glass with argon separation and triple clear glass with air separation while wall construction material varies among double red brick wall with isolation, hollow cement wall, and 0.2m red brick wall. Of Course, if the optimization process has much time for simulation, the Pareto optimal front will have a great improvement.

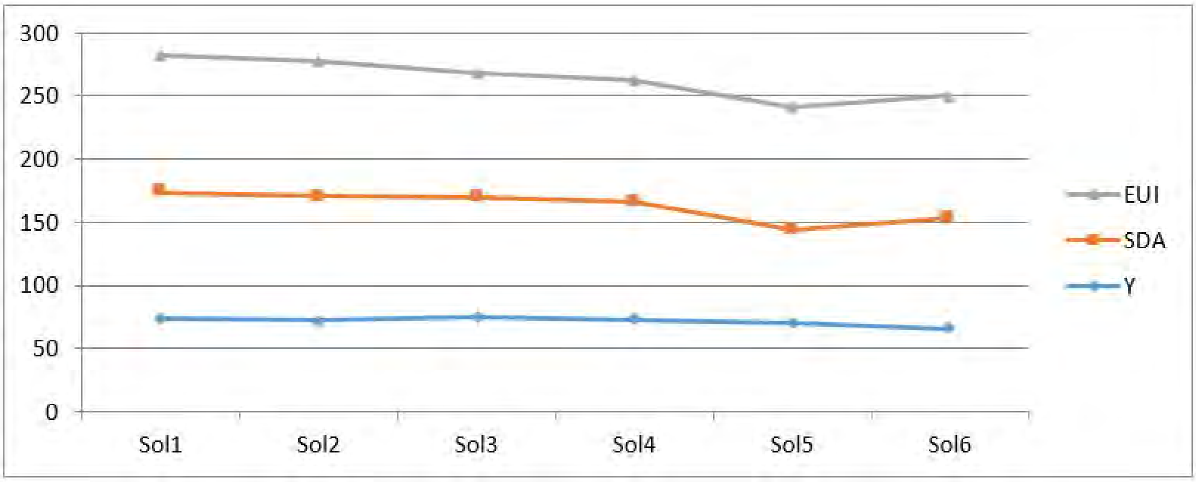
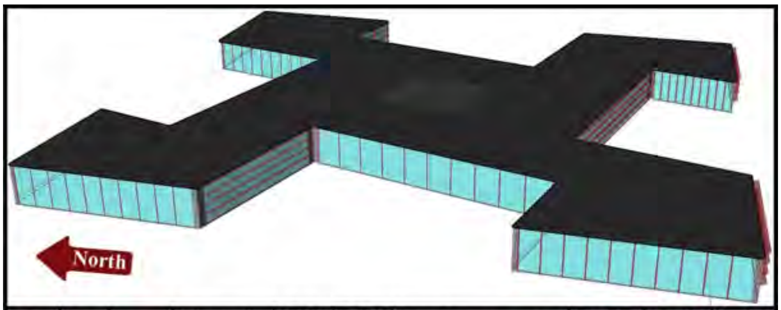


Figure 5. Comparision Between The Solutions of Pareto Optimum Curve.

4.3. The Pareto Front Optimal Solution:

The Pareto front optimal solution is characterized by the balance in the performance of daylighting and energy consumption. So, it achieved the best value of fitness function by 75.33. This genome was produced during the last ”seventh” generation which means that there is an improvement from the previous generation and if there is additional time there will be more optimized solutions in the following generations. As seen in Figure 6, energy use intensity achieved 97.59 kWh/m2 which is higher than the most optimum value for EUI by 22.29 kWh/m2 (29.6%). SDA value has a higher value with 95 which is lower than the optimum daylighting solution by only 5%. This means that the daylighting performance for office space is very suitable.



Y	SDA	Length	Subtraction Diameter	WWR North	WWR East	Wall Construction	Ver.Sh Width	Ver.Sh Count	Ver.Sh Angle
75.33	95	43	10	0.7	0.9	Holow cement wall	0.05	10	°45
	EUI	Width	Subtraction Diameter	WWR South	WWR West	Glass Material	Hor.Sh Width	Hor.Sh Count	Hor.Sh Angle
	97.6	49	°75	0.8	0.9	Double Low-E (Air)	0.4	4	°-30

Figure 6. OptimumSolution Model and Parameters.

Daylighting and energy simulation are analyzed in Figure 7. From these analyses, it is noticed that the day lighting has a uniform distribution allover office zone space which affects significantly on work performance. Also, the outer spaces have a full value of SDA where the office's desktops may be located while SDA value of the deeper spaces decreased slightly. These deep spaces may be exploited as circulation and services spaces which don't need for high values of daylighting illumination.

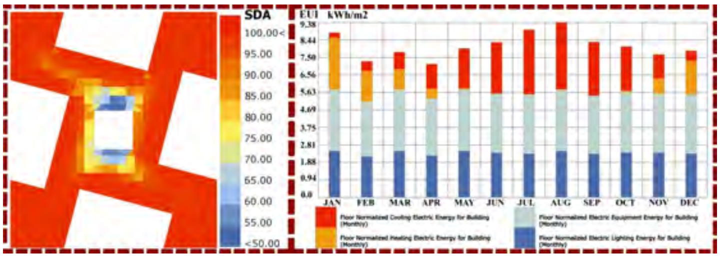
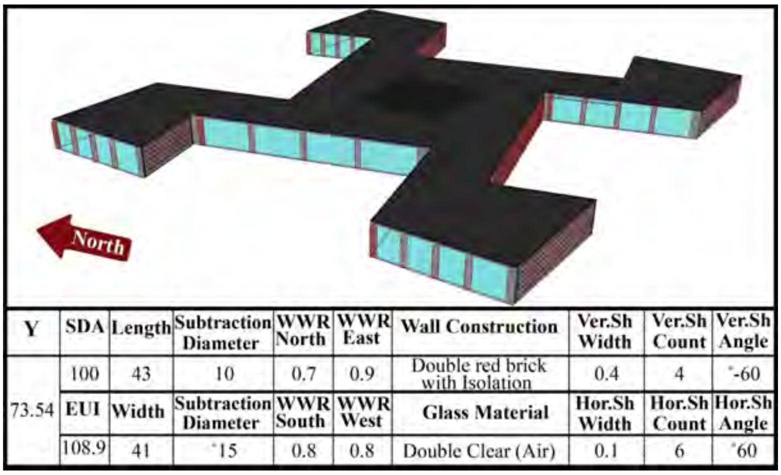


Figure 7. Daylighting and Energy Simulation Results of Optimum ParetoFront Solution.

As seen in Figure 7, The distribution of EUI through the year months showed that the most energy consuming months all over the year are August, July and January which achieve a value of EUI equal 9.38kWh/m2, 9.00 kWh/m2 and 8.90kWh/m2 respectively. Energy consumption increased in August and July because of the high-temperature degrees which need to be maintained by cooling While EUI value risen in January because of the need for excessive heating loads as this month showed lower temperature degrees in Figure 2. The most energy consuming category is electric equipment loads as there are many electric types of equipment in office buildings

4.4. The Daylighting Optimum Solution:

The optimum solution in daylighting performance was produced during the sixth generation in which the daylighting performance has hit the highest point and achieved a full value of SDA by 100. In this generation, the Pareto front optimal solution was the same one which achieved the best daylighting performance. But the high value of EUI compared to the optimal solution, the fitness function value for this genome fall slightly to 73.54 which is lower than the optimal genome fitness by 1.79 (2.4%). This high value of SDA gained because there are large WWRs in east, west, north and south elevations by 0.9, 0.8, 0.7 and 0.8 respectively. As well, shading count has a medium number of vertical and horizontal shading devices by 4 and 6 respectively. In addition, the used glass material is double clear glass with air separation which allows more daylighting to penetrate deeper in the office spaces.



Y	SDA	Length	Subtraction Diameter	WWR North	WWR East	Wall Construction	Ver.Sh Width	Ver.Sh Count	Ver.Sh Angle
73.54	100	43	10	0.7	0.9	Double red brick with Isolation	0.4	4	°-60
	EUI	**Width**	**Subtraction Diameter**	**WWR South**	**WWR West**	**Glass Material**	**Hor.Sh Width**	**Hor.Sh Count**	**Hor.Sh Angle**
	108.9	41	°15	0.8	0.8	Double Clear (Air)	0.1	6	°60

Figure 8. Daylighting Energy Simulation Results of The Daylighting Optimum Solution.

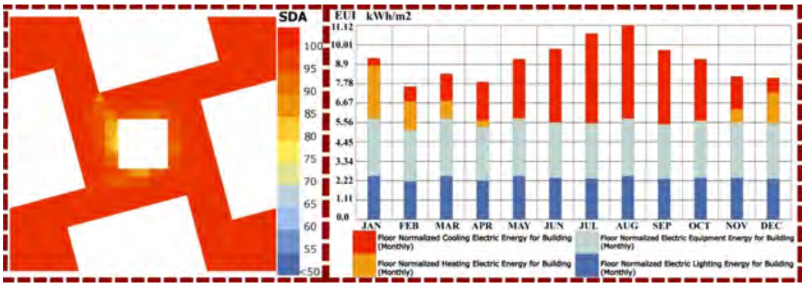


Figure 9. Daylighting and Energy Simulation Results of The Daylighting Optimum Solution.

Daylighting simulation seen in Figure 9 showed a high quality daylighting distribution through case study spaces. The large WWR in the southern facade in addition to the single clear glass material assisted the daylighting to perform higher the than base case by a 117% and by 3.13% more than the absolute optimum genome in Pareto front. On the other hand, this genome achieved a relatively high value of EUI by 108.9 kWh/m2 because of the same previous reasons especially which maintained the daylighting performance especially the clear glass material which has a high U value that allows excessive heat gain essentially in high WWR elevations. As noticed in Figure 9, the heating loads are relatively low compared to the optimal Pareto front solution as the clear glass material allowed the building to gain more heat.

5. Conclusion

This paper focused on representing the details of parametric-based optimization using genetic algorithms in Grasshopper canvas. An office building tower case study in the new administrative capital city in Egypt was introduced to find the suitable plane shape and building configurations for multi-objective optimization to the daylighting levels and energy consumption of office tower building in the new administrative capital city in Egypt through parametric based optimization method. The used metrics for daylighting and energy performance were (SDA300/50%) and EUI respectively. There were many parameters to find the optimum design such as WWR, a glass material, construction material and shading devices in addition to shape parameters. Nearly 350 solutions were produced in 7 generations. Each generation is considered as more optimized from the previous ones. All of these solutions have formed the Pareto front which contains the optimal Pareto front curve where the optimum solution locates on. All of the solutions which are laying on this curve were analyzed to find the optimum solution. While illustrating the optimum solution, it's found that the objective function scored a value of 75.33 as there is a balance between daylighting and energy performance. SDA value was 100 with nearly with a full distribution of daylighting illumination while EUI was 97.6 kWh/m2. The best solutions in daylighting performance as was also investigated. This solution achieved an objective function value of 73.54 as it scored a high value of SDA equal to 100% while the EUI value was 108.9 kWh/m2. The most suitable parameters of office building tower in the new administrative capital city were investigated to be a reference for designers who will be responsible for similar building with the same size and in similar climate and location circumstances. Also, the framework was illustrated to be a guide for environmental and energy modelers.

6. References

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