Environmental Performance-Driven Parametric Design Method for General Hospitals Layout Design

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Abstract. Parametric design driven by environmental performance, a design method integrating parametric modeling, environmental design simulation tools, and algorithm-empowered optimization tools, is becoming increasingly popular among architects when designing building complexes, such as residential, office, and campus buildings, during the early stages of design. However, when it comes to the layout planning of general hospitals, this method has not yet been sufficiently employed. Despite this, it is undeniable that such a method could be effective in assisting architects with site planning for typical Chinese general hospital layout design, which focuses not only on functional efficiency but also on passive design aimed at reducing energy consumption. This paper studies the previous applications of this method in building complex layout planning and proposes a feasible alternative for general hospital planning design. Based on the research, an environmental performance optimization parametric planning program was developed and tested in a specific general hospital design scenario. The program is used to generate multiple optimized layouts of the hospital's core buildings, providing valuable results. Optimization strategies for the tool were then proposed based on the analysis of these results. The potential for application in more diverse and complex scenarios is also anticipated.

Keywords: Parametric design; Environmental Performance; General Hospital; Building Layout Planning.

1. Introduction

In recent years, an increasing number of general hospitals with a capacity of over 1,000 beds have been planned and constructed in China due to the demand for medical services across the nation and the rapid development of domestic medical technology. A large healthcare facility with diverse medical functions presents two major challenges for architects when developing its building layout scheme. The first challenge is, hospital buildings accommodating different functions should be planned rationally to allow them to operate efficiently and cooperatively. The second and equally important challenge is addressing its significant energy consumption. Usage of electricity in general hospitals is 1.6 to 2 times that of other types of public buildings [1] due to greater number of energy-consuming personnel, longer daily operation period, usage of medical equipment and the constant need for maintaining indoor cleanness and comfort. With the advancement of medical technology and the expansion of services, the energy consumption of hospitals exhibits a trend of continuous growth. In response to this, designers must make decision not only about the functionality and rationality of the hospital's buildings in the early stage of site plan design, but also about optimizing the layout to better adapt to the local climate, maximize the utilization of natural resources such as daylight, radiation, and wind, ensuring human comfort, and reduce reliance on electronic services, which has immense potential for energy saving.

Conventional workflows that initial with designing the overall layout and modelling for environmental performance simulation testing, followed by repeated cycles of modifying according to simulation results and further simulation, have certain limitations when designing hospitals. Such design methods are inherently dominated by the designer's personal experience, prioritizing hospital functionality and lacking guidance and constraints from quantitative environmental performance criterias. Additionally, the "trial-and-error" design method, where architectural design and energy-saving simulation are relatively independent, is inefficient and typically only applicable to simple design scenarios, making it difficult to apply to more complicated building complexes with multiple conflicting environmental performance goals. Therefore, environmental performance-driven parametric design method is introduced as a more efficient alternative. [2]

Currently, parametric architectural layout design is mostly based on the Grasshopper 3D platform. Users are encouraged to employ programming thinking to solve relatively complex architectural and planning design problems, forming a workflow that is parameterized, controllable, and efficient. Moreover, combining environmental performance simulation tools such as Diva, Geco, and Ladybug Tools developed for this platform, a workflow of integrating modeling and simulation is created. The introduction of algorithmic optimization design in recent years has allowed parametric design to achieve a closed loop for performance-oriented goals, achieving better interactivity. Among them, the use of genetic algorithm plug-in tools, setting environmental performance goals as evolutionary fitness objectives, and input parameters as "genes," enables a quick global search for Pareto optimal solutions through a process similar to biological evolution's genetic recombination. The parametric modeling program outputs solutions that consider multiple superior performance criterias.[3] This approach possesses the capability of searching for the optimal global solution, parallel processing capabilities, robustness, and good adaptability, making it suitable for solving complex multidimensional or multi-form problems.

The objective of this study is to propose the application of such workflows to address the challenges of functional and passive design in the site planning of general hospitals, based on the exploration and research findings of existing workflows and the design requirements of comprehensive hospitals in China. The study also aims to develop and test out a parametric environmental performance optimization tool for the planning and design of a general hospital, using it to generate and optimize hospital master plan layouts.

2. Performance-Oriented Parametric Workflow with Hospital Layout Design

2.1 Litrature Review

Previously, in the field of environmental performance-driven parametric architectural layout design, studies often involve usage of performance simulation tools such as Archsim, DIVA, Ladybug, Geco with algorithmic tools on the Grasshopper platform, Such as Galapagos and Octopus. The majority of research and practical applications have been predominantly centered on the design of individual buildings, encompassing aspects such massing, form, and facade design. In contrast, much fewer research have attempted to employ this method for creating and optimizing the site planning of groups of buildings. While these efforts are mostly theoretical and conceptual, they offer valuable insights for the application of the method in the master planning of building complexes.

In research of the parametric design for the comprehensive layout of university campus buildings, Xu Ke's team chose to focus on the microclimate of the campus's central courtyard. Their goal was to optimize the year-round thermal radiation effects, UTCI (Universal Thermal Climate Index), and SVF(sky view factor). With a multi-objective optimization tool, Wallacei X, they were able to generate and select better options for locating each building volumes. [4]

In the study of urban wind-heat environment spatial auto-optimization strategies conducted by Feng Jintao and his team, t the parameter settings and auto-optimization process of three uniquely styled square buildings within a specific block was explored. Utilizing the Galapagos tool while setting maximizing wind speed as the primary objective, the team obtained valuable results and was able to established a relationship between building height ratios, spacing, and wind speed within the site to a certain extent. [5]

In a similar research, Huang Chengcheng's team also proposed the 'Building Block Generation Method Based on Wind Environment and Genetic Algorithm.' They developed a parametric program that generates diverse formations of a series of interlinked hexagonal massing while alternating the input parameters. They used the Galapagos tool to sought out solutions that are more meets the optimal goals and achieved the anticipated outcomes. [6]

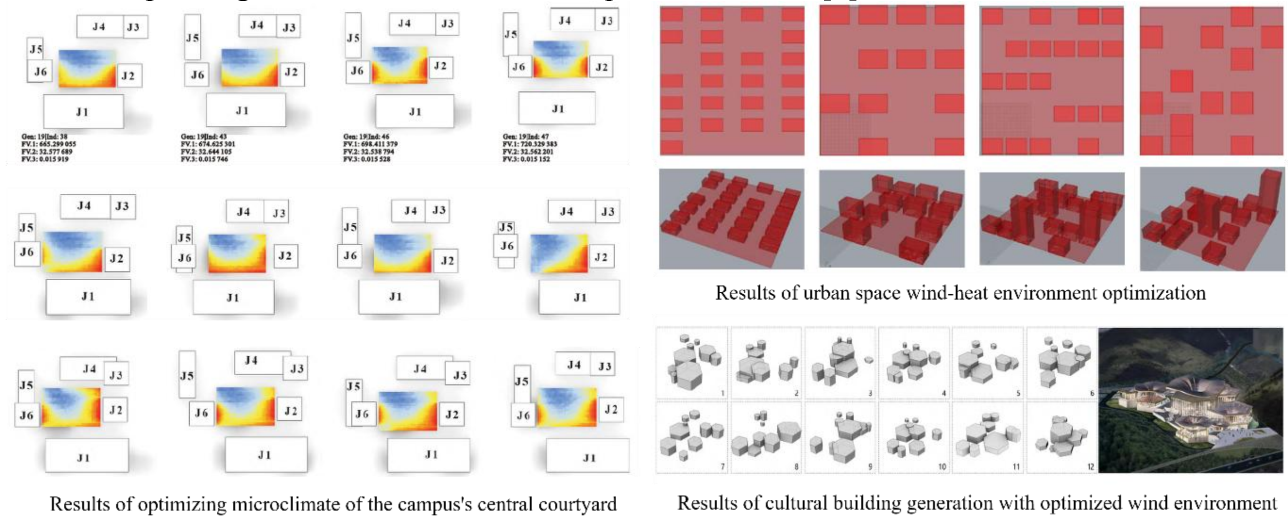


Fig. 1 Applications of the method in planning design different types of building complexes

Source:Xu Ke’s On the Application of Genetic Algorithms in the Architectural Layout Problem;Feng Jintao’s Parametric Design of Building Layout for Intensive University Campus Based on Environmental Performance Optimization. Ecology Building Environment; Huang Chengcheng’s Building Block Generation Method based on Wind Environment and Genetic Algorithm.

To sum up, the application scenarios of such method are confined to planning buildings (schools, residential-commercial complexes) that are relatively simple in form and loosely connected (as shown in Fig.1). Moreover, the parametric modeling has simplified the functional and logical relationships between the buildings to some extent, making it not fully suitable for more complex hospital designs. Nevertheless, it can be concluded that a parametric program base on the general hospitals functional planning logics and strategies is the missing piece of the puzzle. It is crucial to develop a parametric program that outputs the appropriate massing for each hospital function and locates them according to their relevance within the site boundary while setting up certain input parameters.

2.2 Potential of Using the Method in Hospital Layout Design

A typical general hospital in China consists of two sectors, core medical and supplying auxiliary. This study focuses on the core medical sector, where medical activities take place, leads to demand for greater functional and energy efficiency.

The main functional buildings in the medical area include the Outpatient and Emergency Department (OPED), the Medical Technology Department (MTD), as well as the Inpatient Department (IPD). OPED and MTD area are tightly connected, as MTD provides technical and equipment supply to OPED. In terms of patient activity, Patients area most likely to go to OPED for diagnoses and treatment first while visiting a hospital, some of them would be led to MTD afterwards for additional diagnosis and therapy. Therefor a close connection of the two facilities would shorten the routes while providing better wayfinding. The MTD also needs to be closely linked with the IPD, as inpatients require regular visits to MTD for examinations and treatment. Moreover, MTD houses the operating rooms and ICU, and in certain cases, inpatients need to be transferred to MTD for surgery and emergency treatment. Contemporary hospitals in China typically feature a “hospital mall” design, which as its name implied, a mall-like circulation system to connect these three functions. [7]

To adapt to the climate and optimize building lighting and ventilation to the greatest extent, hospitals in different regions usually have specific forms. For example, in China’s Climate ZONE

IV (features hot summer and warm winter), OPED are typically designed with a configuration combined with modules and courtyards, flexibly accommodating multiple outpatient sub-departments. The courtyards allow Indoor spaces of the facility to be showered by natural light, while improve natural ventilation through chimney effect.

IPD wards are often arranged in north-south oriented slab tower blocks, which offering excellent daylighting and ventilation for the ward rooms arrayed on the both sides. MTD, due to their special functional requirements, do not demand for lighting and ventilation as much. Because of that, their design is relatively flexible, though they usually feature a compact and organized layout to shorten travelling routes.

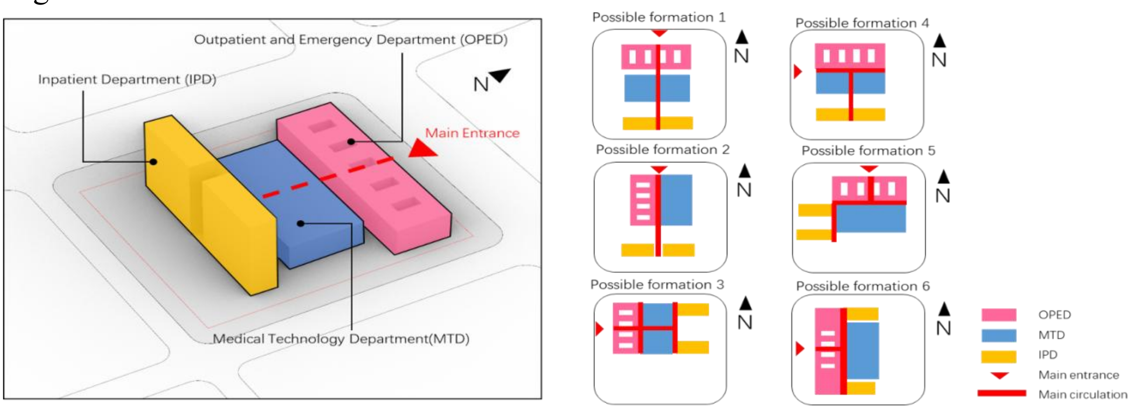


Fig. 2 Architectural characteristics of the three medical function blocks in general hospitals and possible site plan formations according to functional relevancy

Other than daylight and indoor ventilation, the overall layout design of hospital buildings must also consider environmental performance aspects such as solar radiation heat gain, indoor thermal comfort, and outdoor microclimate. [8]

In conclusion, although domestic general hospitals are relatively complex, their individual forms and the continuity between them follow certain patterns, making them suitable for layout design using parametric tools. Additionally, the hospital's environmental performance evaluation is relatively clear, which aligns with the design approach of performance-driven parameter optimization. Using the aforementioned workflow for design holds significant potential.

2.3 Proposing the Design Method for General Hospitals Layout Design

Based on precedent studies of previous performance-driven parametric design application, and acknowledgement of architectural layout characteristics and passive design optimization objectives of typical comprehensive hospitals in China, a performance-driven parametric design workflow tailored for general hospitals (medical sector) layout design in China can be developed. The performance-driven algorithmic generative script consists of three major modules (as shown in Figure 2-2), which is, the parametric model-building module, the environmental performance analysis module, and the algorithm-empowered optimizing module.

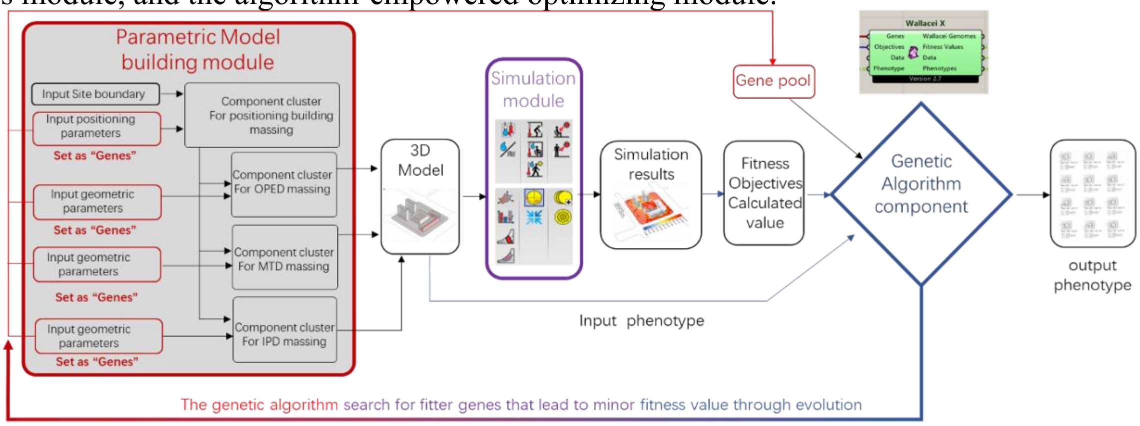


Fig. 3 Flow chart of the environmental performance driven parametric site planning method

The workflow can be divided into three stages. The initial stage involves pre-designing the parametric script. For a script that can generate a properly planned general hospital given input parameters, it is necessary to sort out the essential input variables along with their respective value intervals. To begin with, the allocation ratio of the building floor areas for OPED, MTD, and IPD buildings must be clarified. Other than that, when given the total building floor area of each individual building, single-storey area could be calculated with input values of numbers of buildings and floors. At the same time, single-storey height for each building should be specified to ensure the generated building volume is appropriate. For instance, single storey area of such building usually range from 1600-2000 ㎡ . Therefore, given total floor area, several possibilities of massing allocation solutions for IPD building can be obtained through simple dividing calculation with various building footprint, heights and numbers of buildings. Furthermore, there should be a specific geometric formula for the contour generation of each building, based on which the modelling module can be build up. By inputting key parameters within the specified interval, plans with a reasonable shape and area can be generate for each building unit. In case of an IPD building, it is most likely to be in rectangular shape with a depth ranging from 21m to 30m (housing 2 or 3 lines of rooms), so there will be several results of contour with given single floor areas.

Additionally, based on the spatial relevance between the three types of functions, the logic of planning can be sorted out. The planning script of the modeling program needs to align with this planning typology, being able to locate the proper generating point for each massing accordingly. For example, the outpatient generation point can be located near the possible main entrance edge of the site, and the closely connected medical technology generation point can be derived (e.g., located within a certain distance from the outpatient edge).

The second stage is to set up the parametric script. Based on the preparation during the previous stage, a modeling module could be built with clear hospital planning logic. Subsequently, it is necessary to establish the corresponding simulation analysis module based on the performance objectives. The generated model output from the parametric modeling is fed into the input node of the energy-saving simulation analysis module. Then, the variable parameters of the parametric modeling and the data output of the energy-saving simulation are connected to the gene (gene) end and the optimization objective end (Fitness Objective) of the genetic algorithm computation module, respectively, to form a closed loop.

By this step, tests can be conducted to see if the script can be adjusted and improved. Optimization of the script involves refining the value range to bring it closer to the optimal value and invalidating unreasonable results (null) through the judgment scripts.

The third stage is running the test. The results are obtained through the operation of the genetic algorithm plugin, the scheme model is exported, and the results are analyzed and compared with the aid of visualized charts. Further tests could be carried out to examine how different selected genes and objectives with different input algorithm parameters would impact the effectiveness of the method.

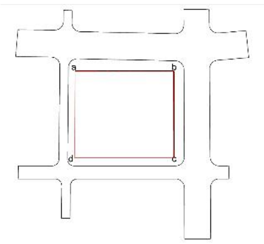
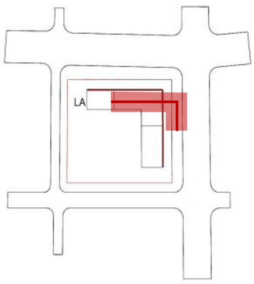
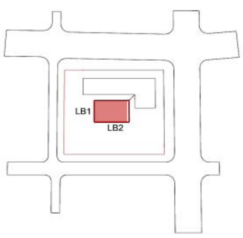
3. Application of the Method in a Practical Scenario

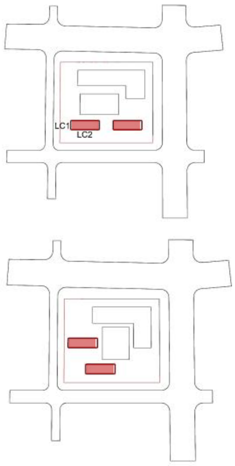
3.1 Scenario Introduction

Building upon the study on environmental performance-driven parametric site planning, an experiment for plan layout generating and optimization of general hospital layout with the method (Program scripted with Rhino Grasshopper2.0 with Ladybug Tools and Wallacei X components was initiated.

The experiment is to design the site plan for a general hospital in a rectangular site in the Guangdong province, setting up four blocks of the three major medical functions, totaling a construction area of 95,000 square meters. The environmental performances objectives for the design include building façade “direct sun hour” on the day of winter solstice as well as summer heat radiation of the overall building complex In the preparation stage, the key information about the scenario was sorted and listed as presented in Table 1, detailing the requirements and constraints for shape and layout as follows:

Table. 1 Key information of the design scenario

GEOMETRIES	PLAN DIAGRAMS	KEY INFOMATIONS	GENES (key input parameters)	FITNESS OBJECTIVES （environmental performance and massing objectives）
SITE		Rectangular site ，entrance of the site could be located along line ab and cd (as highlighted in the plan diagram)		Accumulated radiation gain of the site in summer (from June to September) as low as possible
OPED Building geometry		Generated alone an offset polyline the jointed polyline of ab and cd as its middle baseline Total floor area=LA*lm (length of middle baseline)*nA=30000㎡ Building height HA=nA*4.5	Building depth (LA)30≤nA≤40m） Number of floors nA (3≤nA≤5） Positioning：Lm segment along polyline as highlighted in diagram	Daylight exposure duration on tested surface as long as possible Minimal building height (HA) Minimal buidling foot print (ground floor area) Accumulated radiation gain of the surfaces in summer (from June to September) as low as possible
MTD Building geometry		Rectangle plan parallel to the OPED geometry Total floor area=LB1*LB2*nA =20000㎡ Building height=nB*4.5	Building depth LB1 （70≤LB1≤90m） Number of floors nB （3≤nB≤5） Positioning: offset from OPED geometry with distant of 8-24m	Accumulated radiation gain of the rooftop surface in summer (from June to September) as low as possible Minimal building height (HB) Minimal buidling foot print (ground floor area)

IPD Building geometry		Possible formation as shown in plan diagram Total floor area =LC1*LC2*nA*2(number of buildings)=25000㎡ Single floor area (1600≤ LC1*LC2≤1900 ㎡) Building height HC=nB*4.5+(nC-nB)*4.2	Building depth LC1 （30≤LC1≤40m） Number of floor nC（3≤nC≤5） Positioning: as shown in plan diagram	Daylight exposure duration on tested surface as long as possible Accumulated radiation gain of the rooftop surface in summer (from June to September) as low as possible Minimal building height (HC) Minimal buidling foot print (ground floor area)

(1) OPED with a total construction area of 30,000㎡ requires a 3-5 storey block with a long span (simplified layout where courtyards are not involved) with a depth between 30m and 40m, with a floor height of 4.5m. It has high demand for natural lighting and can be arranged in a straight or corner shape parallel to the east and north sides of the site.

(2) MTD with a total construction area of 20,000㎡ requires a rectangular building with a depth between 70m and 90m and a floor number of 3-5, with a floor height of 4.5m. MTD has low requirements for sunlight exposure and should minimize roof heat radiation. It is closely connected to OPED, with 1 to 2 adjacent edge lines parallel to OPED, with distance between them ranging from 8 to 24 m.

(3) IPD with a total construction area of 35,000㎡ requires two north-south oriented slab towers. The standard floor area of IPD needs to be controlled between 1,600 to 1,900㎡, with a depth between 21 to 23 m. This type of building has high requirements for sunlight exposure and should have a south-facing facade.

(4) The building height of the entire complex should be as low as possible, while targeting a smaller building footprint.

(5) The area where the site is located experiences hot summers. Efforts should be made to minimize the solar radiation reception of outdoor public spaces from June to September to adjust the microclimate of the site and reduce the building's energy consumption of the buildings to some extent. By properly massing and positioning of the buildings, and utilizing building shadows to reduce direct solar exposure on the ground, while also considering the natural lighting for Functions A and C, ensure that the daylight exposure duration on the OPED and IPD facades exceeds 2 hours.

To sum up, it is evident that there are four relatively conflicting and fitness objectives. Detailed definitions of the objectives are listed in Table. 2.

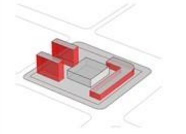
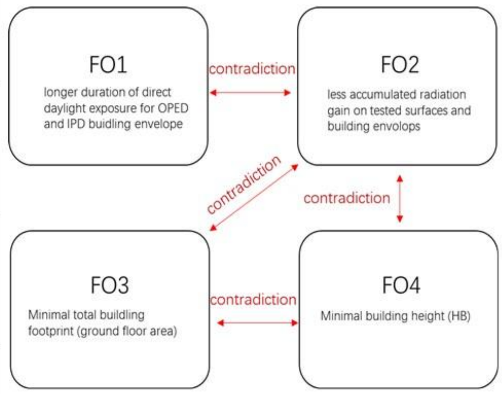
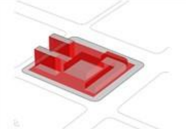
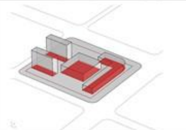
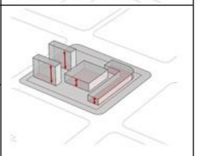
	objective definations	Simulated and measured elements (as highlighted in diagrams)	conflicting relationships between the objectives
Fitness objective 1 (FO1)	longer duration of direct daylight exposure for OPED and IPD buidling envelope		
	finess value FV1= number of cells with direct sun hour less than 2 in total		
Fitness objective 2 (FO2)	less accumulated radiation gain on tested surfaces and building envolops		
	finess value FV2= sum of acculmuled radiation gain of all surfaces		
Fitness objective 3 (FO3)	Minimal total buidling footprint (ground floor area)		
	finess value FV3= sum of groundfloor areas		
Fitness objective 4 (FO4)	Minimal building height (HB)		
	finess value FV3= number of cells with direct sunhour less than 2 in total		

Table. 2 Definitions of the fitness objective and the contradictions

3.2 Parametric Scripting

(1) Parametric Model-building Module

The scripting of the parametric modeling module is based on the shaping logic of general hospital typology. The approach is based on enumeration and shape logic, which involves initially listing as many generation possibilities as possible with the most fundamental arrangement logic, clarifying the generation positioning and outline of the building, constructing the program framework, and generating as many reasonable variations as possible based on this logic by setting and adjusting parameters, defining rules and constraints. This led to developing the steps for generation and location of each block demonstrated in Fig4. While each step creates range of variations, the module is able to generate a great amount of possible solutions.

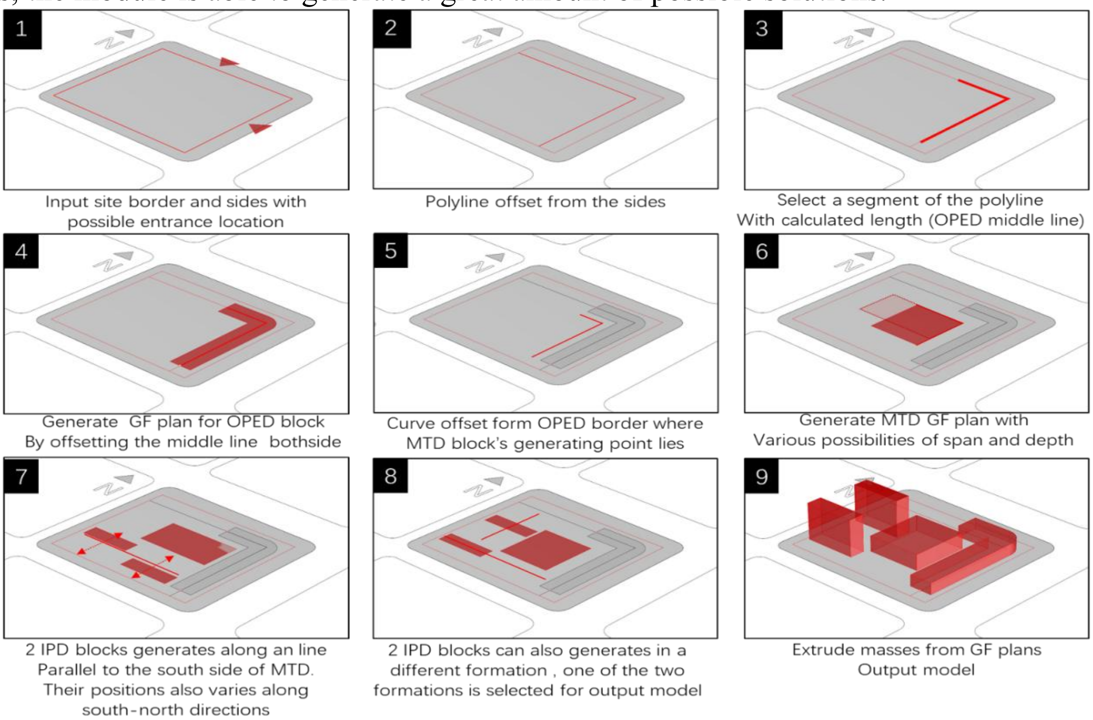


Fig. 4 Steps of generating possible solutions of massing and layout

(2) environmental performance simulation and analysis module includes simulation components such as Ladybug “solar radiation duration” and “cumulative heat radiation”. Running these components requires the input of the epw. (Energy Plus Weather) file of the project site, link the "Sunpath" and "SkyMtx" components, and then feed the outcomes into the solar radiation simulation and heat radiation calculation components. It is also necessary to input the analysis period for testing (for solar radiation simulation, from 9am to 5pm on December 21th; for heat radiation simulation, the entire day every day from June 1st to September 30th). These components also subdivide the surfaces of the test building model selected for the simulation into grid cells, with each cell receiving a result value.

(3) Setting up the Wallacei X components. On the input side of the component, there are the “Genes” and “Objectives”, which are to be connected with the input variables of the model-building module and the simulation outcomes. The simulation outcomes need to be converted into proper “fitness objectives” by solving for minimal values through a series of calculation (as shown in the descriptions in Table.2). For instance, to achieve the best daylight exposure for building facades, the goal is to minimize the number of grid cells where the sun hour duration is less than 1 hour (i.e., insufficient sunlight exposure). Therefore, at the data output stage of the sun hour simulation test, the 'dispatch' component is used to filter data with scores below 1, and the 'list length' component is used to sum up the number of cells with data below 1, which is the calculated number aiming for the minimal value. In this case, while running the algorithm component, groups of input “genes” are selected in the first generation of iteration, and daylight simulation is performed on the generated model, which outputs the value of number of grid cells with less than 1 hour of daylight exposure, in later generations, crossover and mutated “genes” would be selected aiming for a lower fitness value.

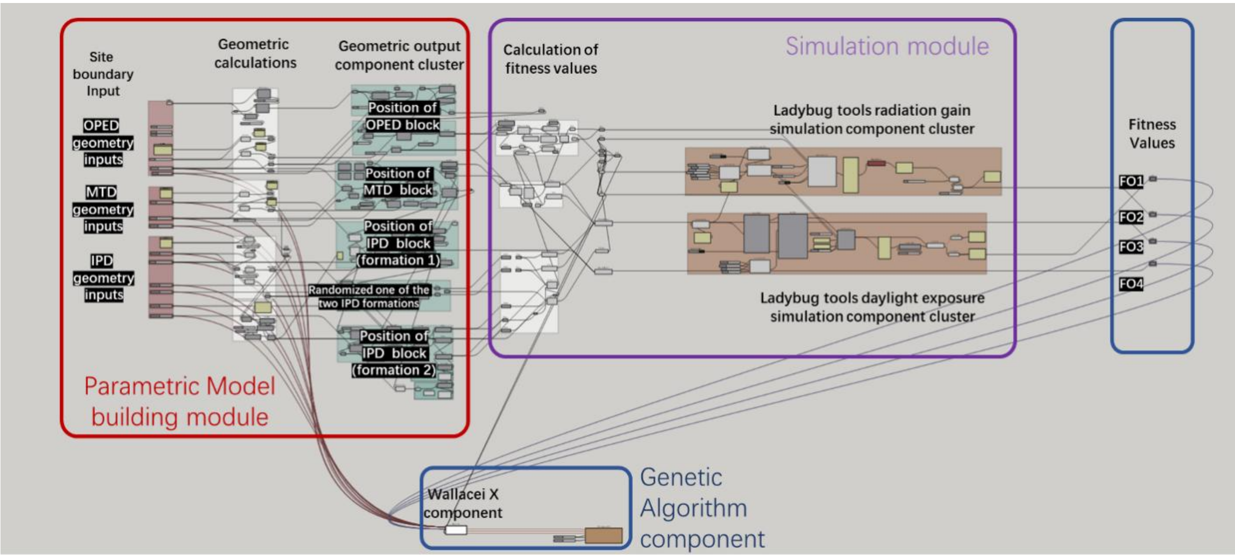


Fig. 5 Scripted component cluster in Grasshopper 3D of the design scenario

3.3 Outcomes of the Experiment

Before running the experiment, several parameters of algorithm and simulation were required to be set up in the Wallacei Setting control panel. The “Generation Size” was set to 50, and the “Generation Count” was set to 50. The “Crossover Probability” was 0.9. Both the “Crossover Distribution Index” and the “Mutation Distribution Index” was 20. The Random Seed was set to 25. After clicking the “Start” button, the parametric script ran for 54 minutes, resulting output includes 2,500 iterations of planning solutions and respective analytical diagrams.

The pareto front solution (generation 49) with a total of 50 schemes was exported (presented in Fig. 6). Among these, the “fittest” solution for objective one (daylight exposure) had a target value of 1,223 (the smallest value on the front), but its target two (heat radiation) value was relatively high, reaching 309,000. In comparison, the smallest value for target two on the front was 281,000, and the value for objective one in the same scheme was also relatively high (1,424). Using the "Wallacei selection" tool, the highest-ranked average fitness (Average fitness rank) within the optimization range was found, with a value of 1,297 for FO1 and 285,000 for FO2, indicating a relatively reasonable optimization effectiveness.

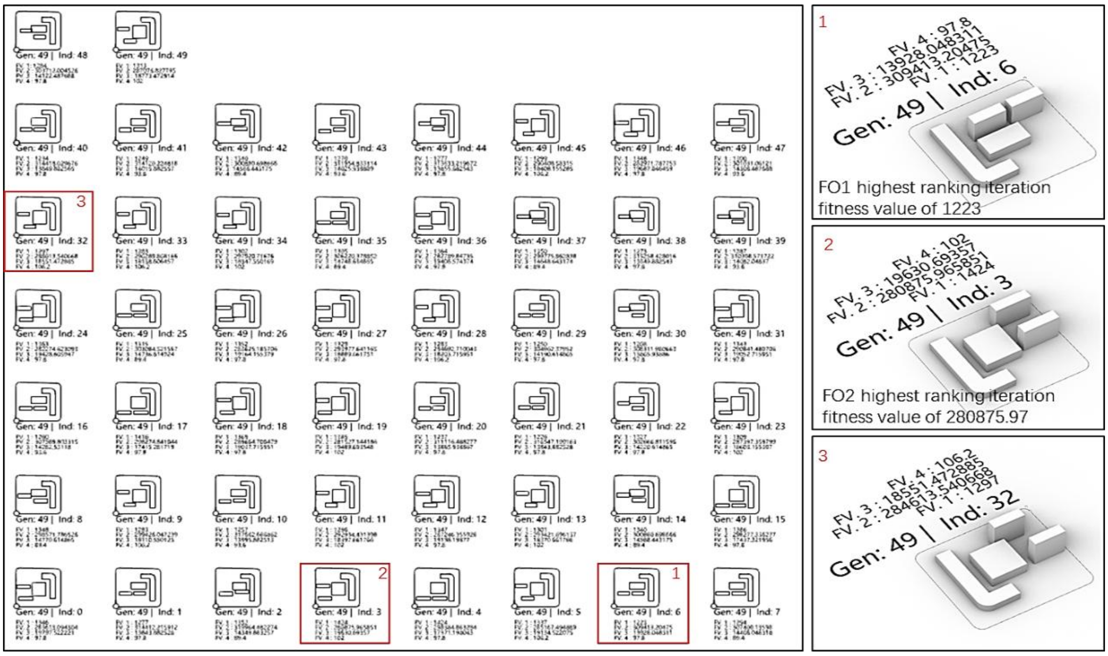


Fig. 6 Output of the pareto front solutions and the highest ranking iterations

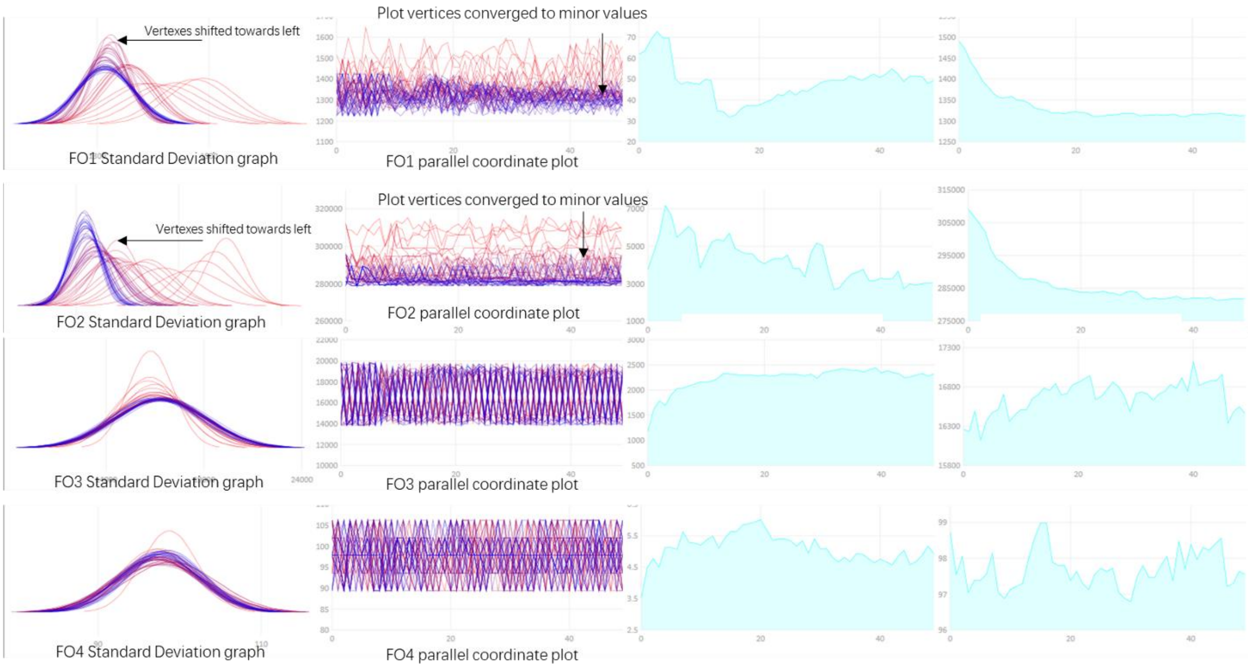


Fig. 7 Standard Deviation graph and Parallel Coordinate plots of each fitness objectives

The Wallacei X component also recorded how each iteration in all generation has evolved, visualizing with standard deviation charts Standard Deviation Graphs and Parallel Coordinate Plot (presented in Fig.7)

In the "Standard Deviation Graphs", each as parabolic curve represents an iteration in every generation. Iterations from earlier generations parabolas are coloured red, and the color gradually shifts to blue in the later ones. The vertex of each curve reflects the repeatability of individuals in the population. If the optimization is performing well, the position of the vertices in the later generations tends to shift to the left side of the horizontal axis (the direction of optimization with smaller values), which means the search for "fitter" genes has converged.

In the Parallel Coordinate Plot, the values of each iteration were plotted on the chart as vertices linked together by a polyline. The position of each vertices represents a value scored for a fitness objective, the lower the position, the fitter (smaller) the value is. The color of the plotted polylines also shifts from red to blue from the initial to the final generation. Therefore, it can be demonstrated that in effective optimization, the initial generations' polyline shows greater fluctuation, and the subsequent generations' line converges towards the lower side with smaller fluctuations, which means the later generations tend to have "fitter" (smaller values).

As demonstrated in these diagrams, the optimization for FO1(sun hour) was the most effective, with the vertex of the parabola being at the 1,500 value on the horizontal axis in the initial generation and progressing towards the 1,300 range in the subsequent generations. The later generation also exhibits repeated genes, as the blue line representing the final generation also appears relatively concentrated at a lower position on the vertical axis. The optimization for FO2 (minimum heat radiation) was not significant in the early stages but showed a trend of optimization in the later stages. Overall, the optimization effects for the two objectives were promising, while the other 2 objectives were not as effective, with the target scores fluctuating around a certain position. Overall, the generated schemes in the experiment somewhat corresponded to the set environmental performance objectives, and the architectural form played a role in guiding and exploring more possibilities. Furthermore, the design results provided valuable insights for designers to understand the changing trends in the arrangement of architectural shapes and performance changes in the subsequent design stages.

After further analyzing and reviewing the experimental results, we found that the experiment still has room for optimization in the following aspects.

(1)Further development of the Parametric Model-Building Script.

In order to have as many as possible solutions to be simulated and optimized, there need to be adjustment in the model-building component cluster as well as redefine of input value intervals. To be specific, the possibility of formation of OPD and IPD is rather limited, which resulted in possible premature convergence during the algorithm search and resulting in front solutions that were likely to be local optimal solutions. The outcome indicated that the OPD block tends to avoid being shaded of the MTD block The OPD block therefore tend to generated as close to the east side as possible, while the variation of IPD layout have little impact on sunlight and reducing heat radiation, eventually preferring a side-by-side layout with better radiation reduction effects. Therefore, it is necessary to further develop the modeling part and explore more layout possibilities, such as segmenting OPD into parts or including more possible IPD formations, such as "L" shape, "boomerang shape", or "U shape", which can be seen in actual designs.

(2)Providing Contextual Information.

Additionally, supplementing the surrounding obstructing volumes of the site, especially those on the south side, can also beneficially increase the complexity of the algorithm and generate better solutions.

(3) Choosing Better Optimization Objectives while reducing the number of genes.

In the experiment, for example, OP4 (overall lower building height) has a relatively small optimization potential and its impact on the opposing target are not very strong. For OPD buildings, there was only 2 stories (9 meters) variation, which does not significantly impact land occupation and daylight exposure objectives. Replacing this optimization objective with one focused on reducing the building's width or smaller building surface area could yield better overall optimization results. Other than this, setting too many input parameters as genes leads to excessive search space, which also reduces the effectiveness of the algorithm, making it difficult to converge.

4. Summary

The environmental performance-driven parametric design method has bridged the two fields of architecture and environmental science. The practical application of the method has been proven to be effective with assisting architects in the cross-disciplinary expertise required for general hospital layout design. With this technique, architects are able to access a wide variety of hospital plan solutions that are functionally logical and have better environmental performance at the preliminary design stage, which makes it significant improvement over the conventional hospital passive design workflow in terms of efficiency and effectiveness.

However, there are some shortcomings and limitations, such as the lack of consideration for the weight of multiple fitness objectives, use of only a simple method of adding indicators; while missing certain contextual information, there could be inaccuracies in some environmental simulations. Also, in some hospitals with even larger scales, where functional network between buildings is more intricate, achieving the expected optimization results is challenging due to the more optimization objectives. Therefore, integrating parametric tools, energy-saving design, and related algorithmic programs still requires further exploration.

The form and layout of hospitals in parametric modeling need further improvement and innovation. Currently, the design workflow under a parametric script lacks considerations in terms of architectural form. It is challenging to include as many layouts as possible under one basic design framework. Therefore, intervention from architects with more aesthetic design elements is still necessary.

The effectiveness of this technique in a specific design context suggests its potential for broader application. Nonetheless, to enhance the workflow's broader applicability, additional research into the layout design of general hospitals is necessary, including schematic approaches for hospitals across diverse climatic landscapes and a wider range of configuration options.

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