AUTOMATING BATHROOM LAYOUT

Automated bathroom layout optimization to improve the flexibility of automation layout

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Abstract. Layout is the process of determining the size and location of rooms and areas. In real life, the work of spatial layout is usually done by designers or by using some automated building layout design software. However, if the designer completes this work, it is not efficient, because the designer and the user need to spend a lot of communication time, and then after the designer continues to modify, the user can get the layout result that he is satisfied with, so the user usually cannot satisfactory results can be obtained in a short time. If the existing design software is used to complete this work, although it is efficient but lacks flexibility, users cannot determine the location and shape of the room according to their own ideas. Therefore, this article attempts to propose a new system for automatically generating building layouts. This system is aimed at the layout of bathrooms in office buildings. However, through the final research, it is found that the system is equally applicable to other spatial layouts. The system is highly efficient and flexible when automatically generating building layouts, and can be applied to most rooms in a building.

Keywords. Space planning; automation; computer-aided design; architecture; computational design.

1. Introduction: (Research context and motivations)

The spatial layout design is one of the most important stages of architectural design. With the development of digital technology, the automated layout is more and more applied in architectural planning. Compared with traditional spatial planning methods, the automated layout has high efficiency, and the automatic generated spatial layout has shown great design potential. But the current automatic space layout still has some limitations, the current automatic generated space layout lacks the flexibility of location selection and shape.

The above-mentioned problems are the problems to be solved in this research. More specifically, this research will design an automated bathroom layout system based on a series of space standards, bathroom rules and laws. The system has high efficiency and high flexibility, and can adapt to many different building shapes, and users and designers can arbitrarily change the area, shape and location of the bathroom, so that users can input data according to different needs and quickly obtain a satisfactory layout effect.

Based on the parametric modeling environment of Rhino and Grasshopper, this research uses a generation algorithm to develop an automated bathroom layout system under the constraints of some collected bathroom rules, laws and user requirements for bathroom layout. From the initial design stage, this article has conducted research and analysis based on different automated layout technologies to explore the best design solutions. And this research is to perform continuous iteration and optimization by analyzing the results of each experiment to obtain the best solution in various situations. The research includes three iterative processes, collecting bathroom-related laws, investigating users' needs for bathroom layout, establishing test models and designing an automated bathroom layout system that can meet both legal and user needs.

The main conclusion is that while following a series of space standards, this algorithm can achieve different results according to different needs in a short time, greatly reducing the workload of the designer. Users can also choose the location, size, and shape of the room according to their wishes, to obtain the most satisfactory results, which aims to improve the efficiency and flexibility of layout work.

The significance of this system is to reduce the designer's workload on the spatial layout, making the spatial layout simpler, efficient and flexible at the same time. Users can also use this system to obtain satisfactory results according to their requirements in a short time, which also contributes to the improvement of the automation layout.

2. Research Aims

This research aims to design an automated bathroom layout system that can meet the legal and user requirements for bathroom layout. The system is developed based on two tools, Rhino and Grasshopper. The system has high efficiency and high flexibility. More specifically, the system allows users to change the number, location, size and shape of bathrooms in accordance with the law and their own requirements. And the user can see the result of the layout in real time, thereby obtaining a satisfactory layout.

3. Research Question(s)

There are two problems to be solved in this research：

1. How to make automatic space layout more flexible?

2. How to better use automatic layout to plan the location of the office bathroom to meet the legal and user requirements for the layout of the bathroom?

4. Methodology

Action research is a name given to a particular way of looking at your practice to check whether it is as you feel it should be. Research action is part of critical thinking about your practice, or perhaps a response to a professional development review. The idea of action research refers to the theoretical framework and organising principles that guide practice(McNiff, J., 2013). It combines theory and practice, researchers and practitioners, as well as intervention and reflection. Action research is divided into five stages, which are diagnosing, action planning, action taking, evaluating and specifying learning (O'Brien, R. 1998). I will apply these five stages to the research of my project.

1. Look up and read some literature about my research project to identifying or defining a problem.
2. Develop an overall plan for achieving goals (make a flowchart showing clearly what should be done and how each phase should be done).
   - Research (regulations, requirements and legal)
   - Modeling
   - Scripts
3. After making the overall plan, I will start the real action to implement the program created in the second phase and start my project production.
4. After the completion of the project, it is necessary to evaluate the project

and assess whether the theoretical effect of the project has been achieved. If not, it must reflect and make some modifications, and then start the next iteration of the action research cycle until the goal is achieved.
- Optimization1, optimization2, optimization3……optimizationN
- Outcome

5. It is a learning process to make a summary of the whole research project and summarize the knowledge learned, experience gained and reflection after failure in the research.

5. Background Research/Literature review

"Algorithmic solutions to spaced distribution problems were first developed more than 30 years ago" (Jagielski, & Gero, 1997, p875). So far, many techniques have been developed to optimize layout problems. The first try to automated layouts date back to the early 1960s (Schneider, S., Fischer, J. R., & König, R. 2011, p.367). "The same brief for a house may generate solutions of breathtaking sophistication and mind-numbing banality" (Hanson,1998, p.2). Generally speaking, the spatial layout is a very complex problem. As the number of possible solutions grows exponentially, even a small amount of space creates a tremendous amount of search space (Doulgerakis, A. 2007, p14). With the increasing need for computerized facility planning and management, automated space layout products are likely to play an even more important role (Liggett, R. S. 2000, p.197). Recently, such space distribution problems have been brought to the attention again, resulting in solutions using genetic algorithms (Jo and Gero 1997). Therefore, the purpose of this review is to carefully evaluate how best to complete the automated space layout to get the best results to guide the research on the automated layout.

The layout is the process of defining the size and location of visual objects as part of an information representation (Lok, S., & Feiner, S. 2001, p61). In an automated layout design, take into account the various aspects that will affect the final result. In the spatial phase, the architect analyzes, integrated the client's needs, synthesizes desires, legal requirements, topographic constraints and aesthetic preferences, which may be possible to contribute to the final design (Rodrigues, E. 2014, p3). The first challenge for automated layouts was to extend the incomplete and high level of customer requirements into detailed specifications for the home (Merrell, P., Schkufza, E., & Koltun, V.2010, p3). Before the automation of layout design, designers need a lot of information, such as customer requirements, legal requirements, and then get detailed data based on this information, and then write the script. Before starting to write the script, architects need to have a complete requirements system. Besides, during the design process, the requirements of users may always be changing, so a new full layout needs to be obtained according to the changing data to meet the requirements of users and laws. The designer must be able to see the results and impact of his

actions immediately after the design is completed. (Schneider, S., Fischer, J. R., & König, R., 2011, p.367). This shows that in the design process, the system must run in real-time so that users can immediately see the results of parameter changes and participate in them, thus shortening the design time and improving the efficiency of the whole project, so as to achieve the best design effect.

The genetic algorithm plays an important role in automatic spatial layout. “Genetic Algorithms (GAs) model natural selection and the evolution process. Conceptually, genetic algorithms use the mechanisms of inheritance, genetic crossover and natural selection in evolving individuals which, over time, adapt to their environment.” (Gero,1996, p.16). Since spatial layout planning is challenging to be formulated and solved by algorithms, evolutionary methods, mostly genetic algorithm (GAs), have been widely used to solve the optimal solution on a large solution space (Chen, C., Chacón Vega, & Kong, 2020, p2). The work of Gero, & Kazakov, (1998) proves that the genetic algorithm can find the solution more quickly, but this study only involved a particular project, therefore it lacked universality. Chen, Chacon Vega, & Kong, (2020) the importance and advantages of genetic algorithm in the automatic design are emphasized. This is an effective way to find the best solution from a large number of alternatives within a short period. Compared with other methods used in architectural design, this is a lightweight tool that is less complex, expensive, and cumbersome (Chen, Chacón Vega, & Kong, 2020, p15). The general iteration method are prone to fall into the trap of local minimum, and the phenomenon of "infinite loop" appears, making it impossible to carry out the iteration. The genetic algorithm solves the problem well and is a global optimization algorithm. In general, genetic algorithms enable architects to perform better automated layout designs for better results.

The purpose of this review is to study how to accomplish the automated layout design better. Although the data on the automatic space layout is limited, these studies provide very effective methods and algorithms (genetic algorithm) to enable designers to complete the automatic layout design better. Liggett, R. S. (2000) described the past, present, and future of automatic facility layout. This article enables designers to have a clear understanding of the knowledge and technology of the history and present automatic layout and allows designers to find the direction for future research on the automatic layout. In the future, I will further research the automatic layout design.

6. Case Study

The case study includes three aspects, collecting and studying the legal and user requirements for the bathroom in the office building, designing a testable model and an automated bathroom layout system that meets the legal and user requirements for the bathroom.

6.1 RESEARCH(ITERATIZON)

According to the research goals, this project should meet the rules, laws and different needs of different customers for the establishment of bathrooms in office buildings. Therefore, it is very important to collect and study this information. This information will help me find the specific problem to be solved more quickly and save time for research.

How many bathrooms are required in a workplace?	
Number of workers	**Number of bathrooms**
15	1 unisex bathroom
16-35	2
36-55	3
56-80	4
81-110	5
One additional toilet for every 40 employees	

Figure 1.The number of bathrooms are required in a workplace

The first is to study the rules and laws regarding bathrooms. According to the regulations of SafeWork Australia (SafeWork Australia), every workplace must have bathroom facilities. If a company with less than or equal to 15 employees only needs to provide a lockable unisex bathroom, and the requirement for a large company is that the number of employees is between 16 and 35 to provide 2 bathrooms for the employees to use, employees The number of employees between 36 and 55 must provide 3 bathrooms, the number of employees between 56 and 80 must provide 4 bathrooms, and the number of employees between 81-110 must provide 5 bathrooms. Besides，one additional bathroom for every 40 employees over 150. These practices are designed to prevent long queues and ensure that employees can quickly use bathroom facilities. Through the above research, it can be determined that the first task of this project is to design an input system so that the user only needs to perform simple operations in the layout system and directly enter the required numbers to obtain the corresponding number of bathrooms, to meet the above rules and laws.

In addition to the above rules and laws, there are some requirements that must be followed. For example, the bathroom should have sufficient lighting and ventilation to meet the staff's requirements for bathroom hygiene and better use of the bathroom. In addition, the bathroom must have a safe escape route, that is, the bathroom must be connected to a safe passage, to avoid that the staff cannot escape safely in the event of an accident.

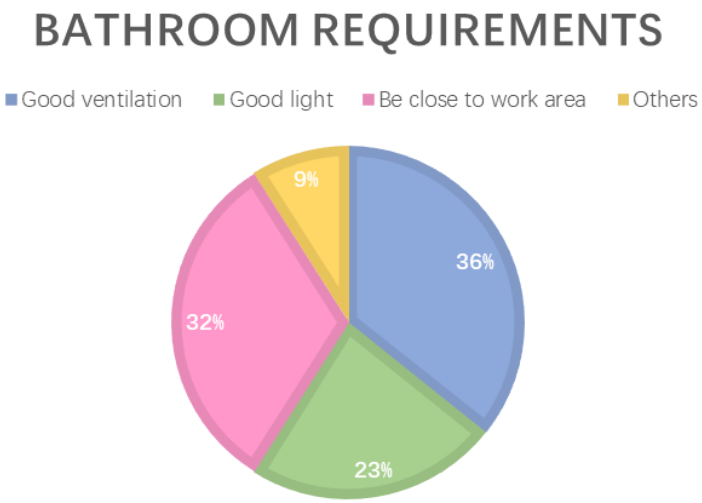

Figure 2. Bathrooms requirements

Another goal of this project is to meet the needs of customers, so it is very important to collect their opinions. For this reason, I conducted a questionnaire survey on 25 randomly selected staff. Most of their working environments are different, so such survey results are diverse. As shown in Figure 2, after sorting out the questionnaire, it was found that 36% of the respondents believed that good ventilation in the bathroom is very important. Specifically，good ventilation will reduce the odor in the bathroom and increase the comfort of the user, and this is the same as the legal requirements for the bathroom. The second important issue that users pay more attention to is to hope that the bathroom can be close to the work area, so that the time spent in this aspect can be reduced. At the same time, some users have other needs. Through the above investigation and research, it can be determined that the second problem to be solved by this project is to allow users and designers to change and determine the location of the bathroom at will by using this system, so that they can base on the location of the windows of the building, the location of the work area and other The condition is to change the location of the bathroom to meet its requirements.

6.2 MODELING (ITERATION 2)

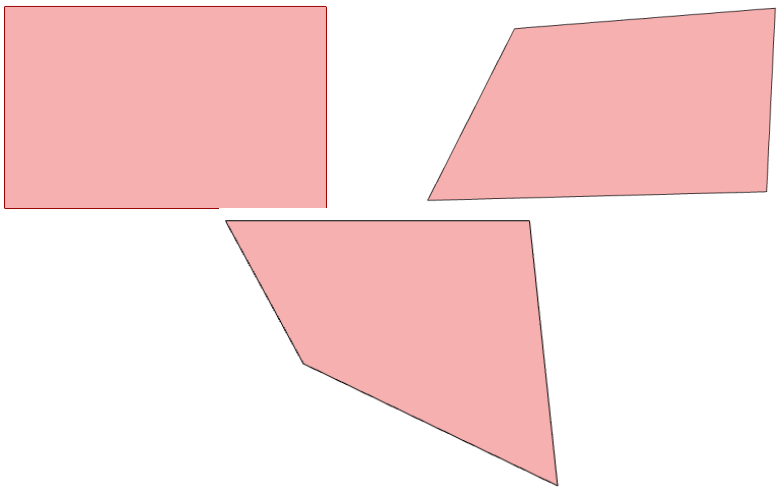

Figure 3. Different architectural plan

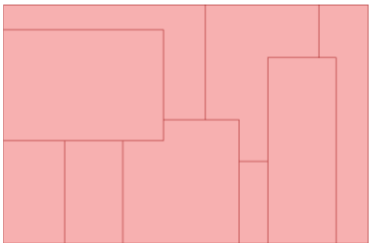

Figure 4. Floor Plan (Modeling)

Because all layout work is carried out in an existing building, the second step of the project is modeling. And as an automatic layout system, it must be able to adapt to different building shapes to get a complete layout. Therefore, through Grasshopper and Rhino, I built many different shapes of building grounds (Figure 3) to provide the basis for the design and testing of the next project. And to test whether this system can be selected in different areas for layout, I also established a complete building layout plan (Figure 4).

6.3 AUTOMATED BATHROOM LAYOUT SYSTEM DESIGN (ITERATION 3)

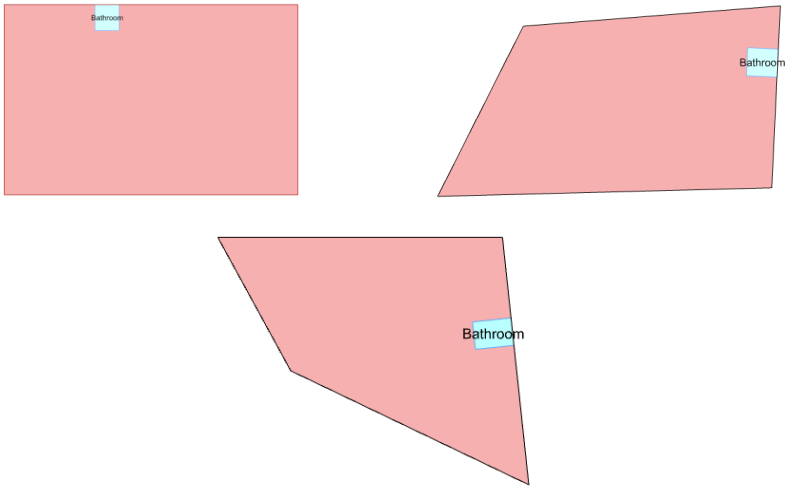

Figure 5. Adapted to different building shapes

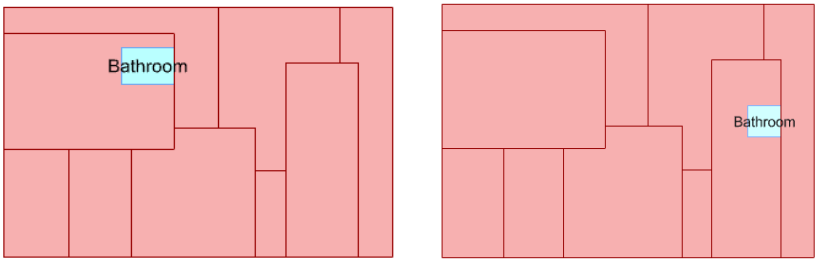

Figure 6. Adapt to different layout areas

After establishing the test model, the next step is to solve different problems step by step. At this stage, more in-depth exploration of what kind of design will improve the flexibility of automated layout. According to the design goals, the first thing is to design an automated layout system that can adapt to different building shapes. In order to achieve this goal, Grasshopper and Rhino were used in this design. By analyzing the existing building plan, the system can be used to layout the bathrooms in different buildings (Figure 5). Since the location of the bathroom is not only on the edge of the building, but may also be located in different areas within the building, as shown in Figure 6, by separating different areas in the building, the user can select different areas and then proceed to the layout of the bathroom , and users can see the real-time results of the layout.

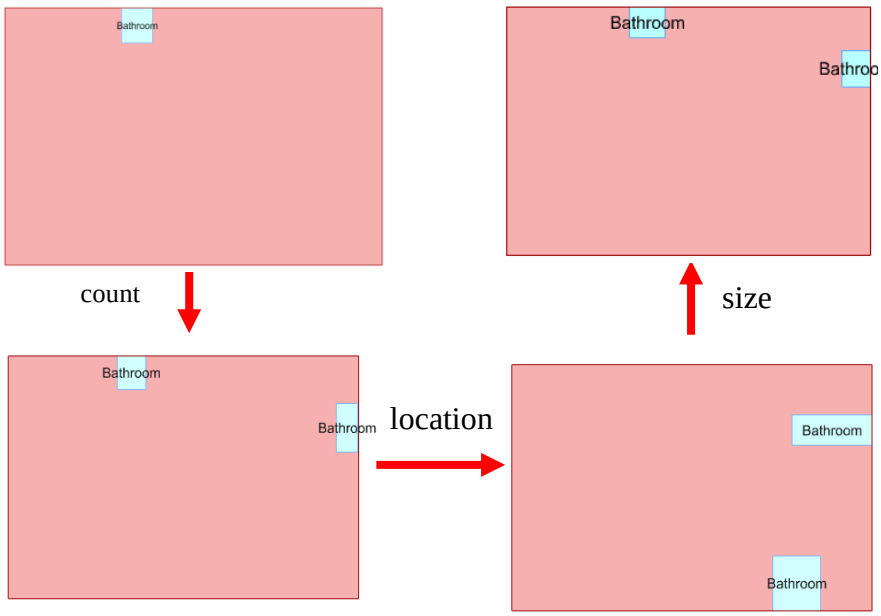

Figure 7. *（Adapt to different layout areas）*

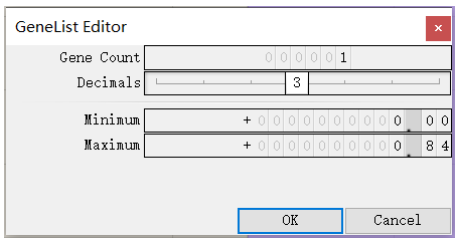

Figure 8. Control the number of bathrooms

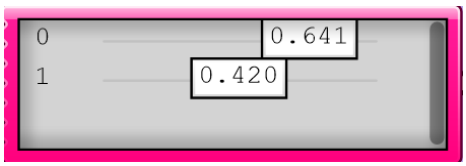

Figure 9. Control the location of bathrooms

Through previous design and testing, it has been proved that this system can perform normal layout work under different building shapes. The subsequent work aims to design an automated layout system that can meet the rules, laws and user requirements for the bathroom. In the first iterative analysis, it is concluded that the main task is to solve the problem of the

number of bathrooms in order to meet the legal requirements for bathrooms. Specifically, the system should enable users to change the number of bathrooms according to different needs. To make it easy for users and designers to use, I designed an input system. Users and designers only need to enter the number of bathrooms according to their needs (Figure 8), and they will get the same number of bathrooms in real-time in the floor plan (Figure7). In order to meet the needs of users for the bathroom, the main task is to allow users and designers to change and determine the location of the bathroom at will through this system. In this respect, I also designed a device that allows users to simply control the location of the bathroom. As shown in Figure 9, in the system, the user only needs to slide the slider to change the position of the bathroom at will, and can control the positions of different bathrooms separately. In this way, users and designers can change and determine the location of the bathroom according to the location of the building's windows, the location of the work area, and other conditions to meet the requirements of laws and users for the ventilation and lighting of the bathroom.

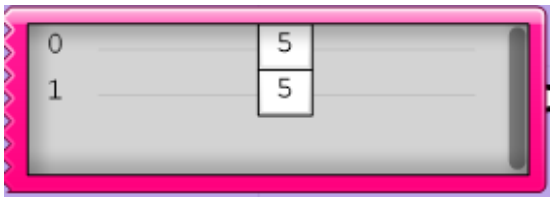

Figure 10. Change the size of the bathroom

As shown in Figure 10, in addition to the above design, in order to meet more needs of users, I also made a design. In this system, the user can also directly control the size of different bathrooms by moving the slider, and the user can see the real-time results of the layout (Figure 7) and make different adjustments at any time.

All of the above designs meet the requirements of the law and users for bathrooms, improve the flexibility of automated layout, and users can see the results of the layout in real-time, which is highly efficient.

7. Discussion

The results of the above three iterations have studied user needs and bathroom laws to a certain extent, and then designed an automated layout system that meets these needs to achieve the preliminary goals of the

research. In the first iteration, by collecting legal requirements for bathrooms and a questionnaire survey of 25 staff from different working environments, the specific problems to be solved were summarized and a clearer design direction was given. Then, the second iteration used Grasshopper and Rhino for modeling, which allowed the design and testing of the following projects to proceed better.

"Action research is divided into five stages, which are diagnosing, action planning, action taking, evaluating and specifying learning" (O'Brien,1998). These five stages are very helpful and very important for project research. At the end of the research project, the evaluation and reflection on the project will help us learn more knowledge, discover the problems of the project, and improve our project in future research. Therefore, although the results of this project have reached the standard, through the evaluation and reflection of this project, it is found that this project still has certain limitations and some problems. Therefore, there are two aspects that need further research in the future work.

First of all, according to experiments and tests, the system can only be applied to rectangular buildings at present, and satisfactory results cannot be obtained for some circular buildings. And because there are many different building shapes, it is impossible to test each building shape during the research process, so it is not sure whether the system is suitable for other building shapes other than circular. Secondly, through the collected laws, we can know that the number of bathrooms is determined by the number of employees in a company. Therefore, a system should be designed in which users can automatically determine the number of bathrooms only by directly inputting employees. In this way, before the automatic layout, the user does not need to spend time to calculate the number of bathrooms required, reducing the time spent by the user, but this problem has not been solved yet. These two aspects are the aspects that have not been studied in this project. Therefore, these problems will be solved in future research to make the project more perfect.

8. Conclusion

It focuses on designing an automated bathroom layout system, and then users can use this layout system to meet the law and their requirements for a bathroom layout, which allows users to obtain their satisfactory layout results in a simple way. After three iterations, it turns out that the automated layout system designed in this project makes the layout easier and more flexible, reducing the time spent by designers and users on spatial layout, and users can get their satisfaction layout to result in a short time. Although

there are some limitations to this project, this result shows that the project has achieved the goals originally set.

In general, this research has designed an automated layout system based on satisfying laws and user requirements for toilets, and this system has high flexibility and efficiency. More specifically, this system reduces the user's restrictions on automatic layouts, such as not being able to choose the location of the room, etc., and users can more according to their ideas to layout space, to obtain satisfactory layout results. However, this research can be further developed in the future.

Acknowledgements

I would like to thank Nicole Gardner, Hank Haeusler and Daniel for proving help and valuable feedback throughout this year. Also, thanks to my parents and friends for their encouragements and supports through the project.

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APPENDIX A: QUESTIONNAIRE KEY NOTES IN ITERATION 1

Questions	Results
What are your bathroom layout and other requirements	36%- Hope the bathroom has good vents, close to the window 32%- Hope the bathroom is closer to the work area 23%- Hope the bathroom has good light 9%-others