A facade design idea generation support system through evolutionary computing

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Abstract

In recent years, design methods using algorithms have been incorporated into the designs positively. Creativity support systems can be expected to eliminate the problem of design ruts. In particular, geometric shapes have infinite design pattern, therefore creativity support system will lead to the possibility of greater designs.

In this study, facade design is generated by dividing areas using straight lines. The various product designs will be possible by devising the setting of the parameters.

Keywords: façade design, idea generation support system, evolutionary computing, IDES,

Introduction

The person's way of thinking has limitations, for it is dependent on the person's own experience or environment. For this reason, we are concerned about the problem of design ruts. A geometric form, such as that shown in Figure. 1, can have infinite design patterns, and thus a more wonderful design may exist in patterns that surpass our own imaginations.

Even if we are able to imagine beautiful architectural designs, these must be realized within an actual structure. In response to this problem, the use of an idea generation support system which proposes a design might be an effective solution, and we have been carrying out various studies for that purpose.

In recent years, complicated structural analysis has become possible through improvements in computer performance.

Figure. 1 Reference examples of building

System summary

1. The design creation technique

Arbitrary points are placed at circumference freely, and then random lines which connect arbitrary two points are set up. These lines divide the surface of a wall and opening design is generated.

1) Cell division and placement of the free points.(Figure.2)
   Set the points freely to vertical and horizontal circumference. Facade is divided to cells, and is able to handle with each cell.
2) Placement of random lines. (Figure.3)
   Designate the lower and upper limits of the number of lines connecting points. The cells on the lines are the wall. Set whether multiple lines from the same point are permitted. Figure 3 shows an example in which it was not permitted to set multiple lines. The following are conditions for the lines:
   - The lines do not overlap with each other.
   - The line you have set does not overlap with lines of the circumference.
3) Making the opening and wall. (Figure.4)
   Calculate the area of each compartment (number of cells) that is divided by the lines. Set as the opening in order from the small compartment until opening ratio reaches the designated value. In this case, the user sets the minimum area of the opening by consideration of construction process and design evaluation. No compartments below the minimum area can be set as the opening.
4) Setting openings not adjacent to each other. (Figure.5)
   As shown in Figure 4, a design with openings born in succession gives a poor design impression. Therefore, in order to prevent continuous openings, the centroid of each compartment must be calculated at first. If the number of intersection of the boundary line and the centroid between each compartment is one, the opening processing does not perform as adjacent compartments.
5) Structural analysis and study
   Structural analysis performs two cases, one is a frame structure in which the structure is only a portion of the line, and the other is wall structure as whole facade. The analysis is performed with FEM analysis by applying a uniform load to the mesh nodes of the floor of each layer. Consider the structure performance by indicating analytical results such as the danger figure and the stress contour figure. Danger figure is diagram showing a cell stress equal to or greater than the specified value has occurred.
6) Link with the IDES.
   Incorporate the parameters as gene locus to the IDES (Interactive Differential Evolution with Score). A new design which matches the sensitivity of the user and satisfies the opening ratio is proposed by the IDES.

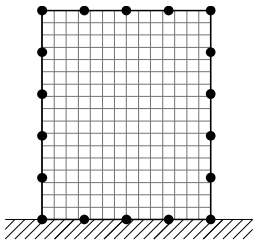


Figure.2

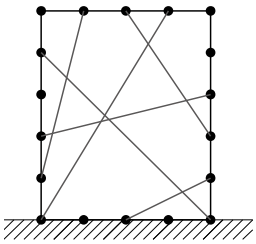


Figure.3

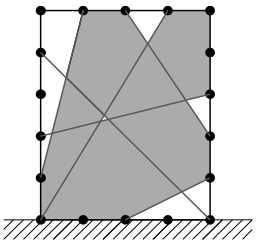


Figure.4

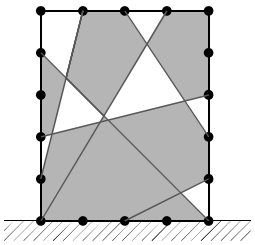


Figure.5 Final image

2. System Flow

There are two methods for the form creation, one is evolutionary computation technique which is determined by subjective evaluation by interaction with users and computers, and the other is the method of obtaining the optimal form numerically analytically.

The forms that stimulate the ideas of the user and the forms that have the functions desired by the user can be gained efficiently from the many forms to be presented, by using evolutionary computation techniques.

Our laboratory proposed IDES, and adopted IDES as evolutionary computation technique of design in this system. In IDES, it is necessary to impart a score according to the preference of the user in the paired comparison. Therefore, to reflect the selection of the parent individual of the next generation, a score is given to each individual according to the preference of the evaluator.

In this occasion, this system displays a dangerous figure and stress contour figure of analysis results so that user can take into account the mechanical properties.

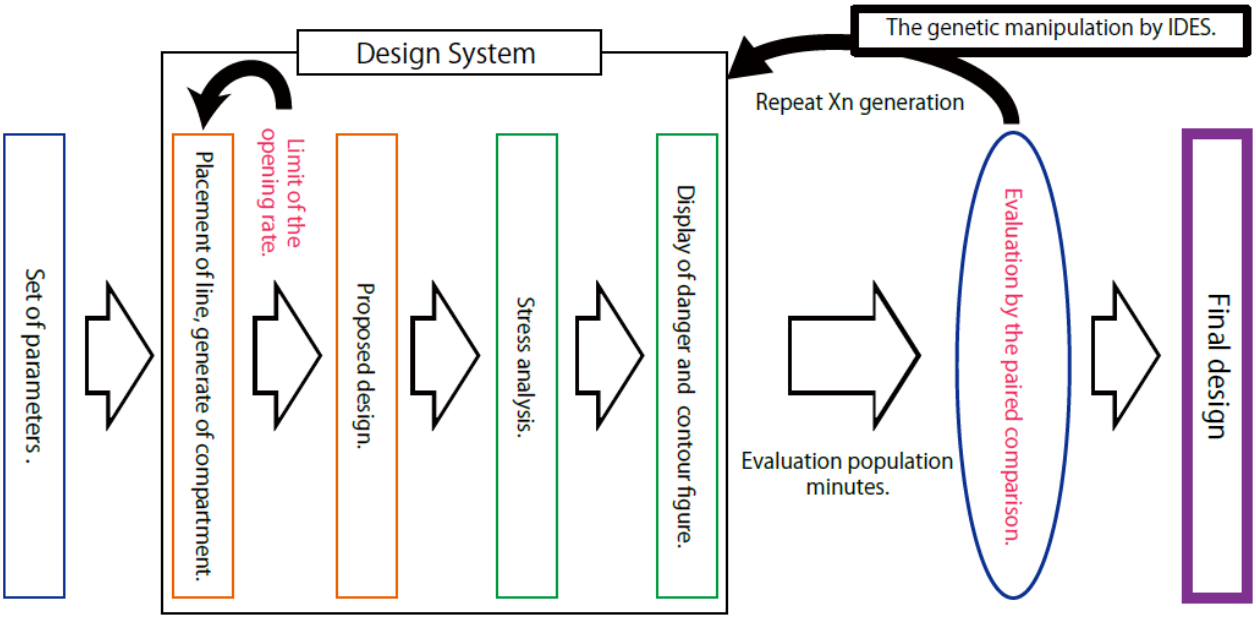


Figure.6 System flow

The example of execution, and validity

Figure 7 shows the program execution screen. Figure 8 shows various examples for changing the number of layers, nodes and lines.

The validity of this system was examined by the possibility of generating designs similar to the facade design of the building of Fig. 1. (Figure.9)

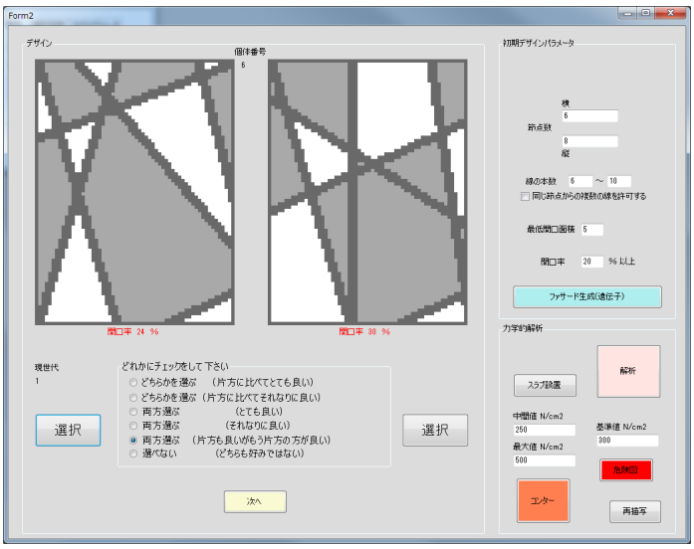


Figure.7 System screen

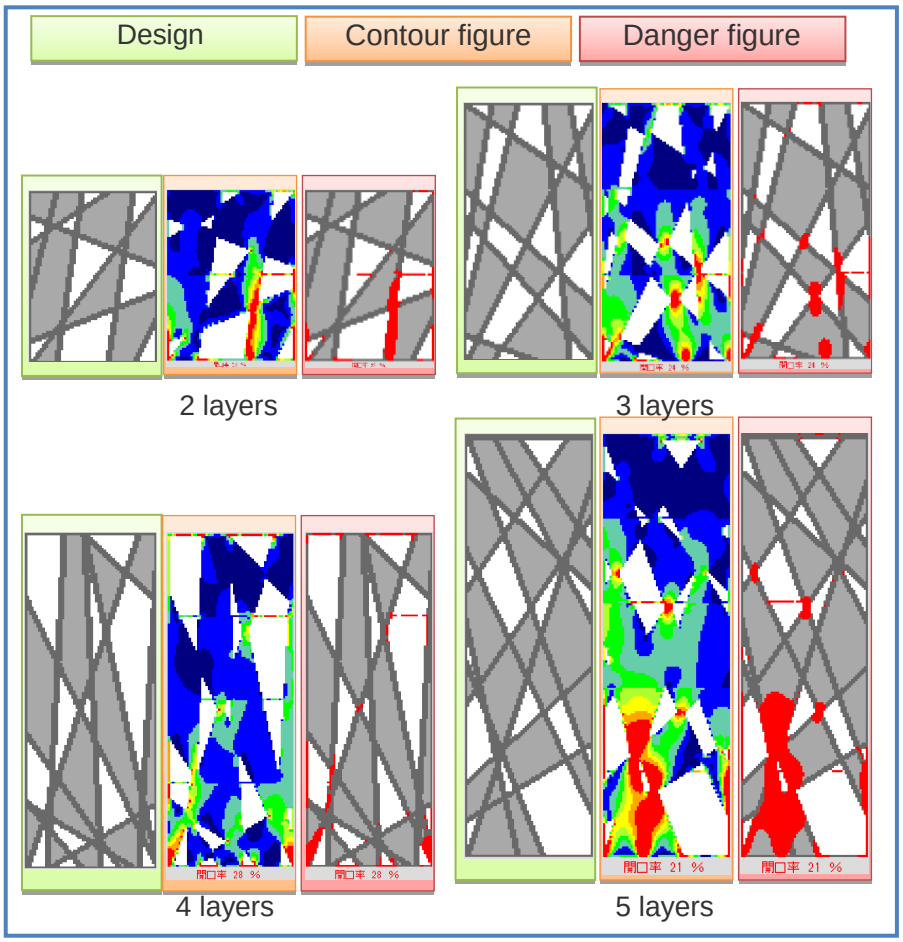
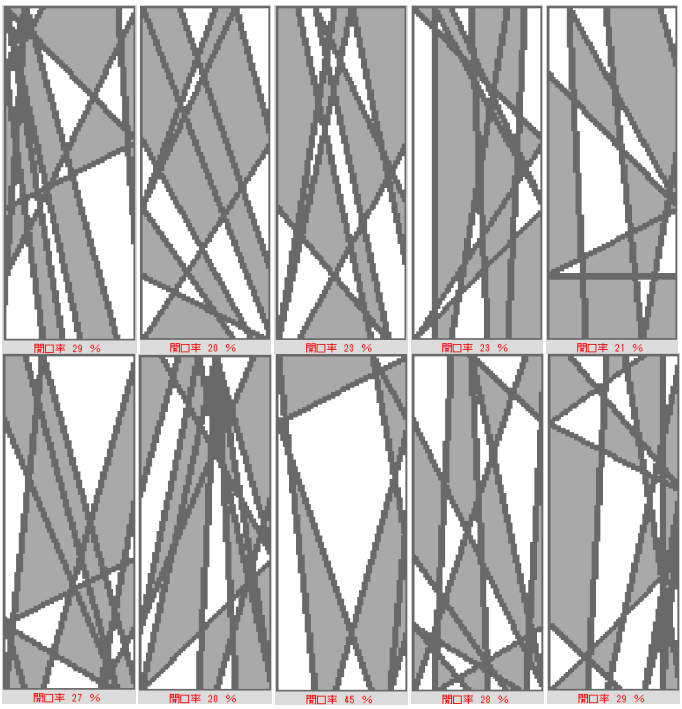
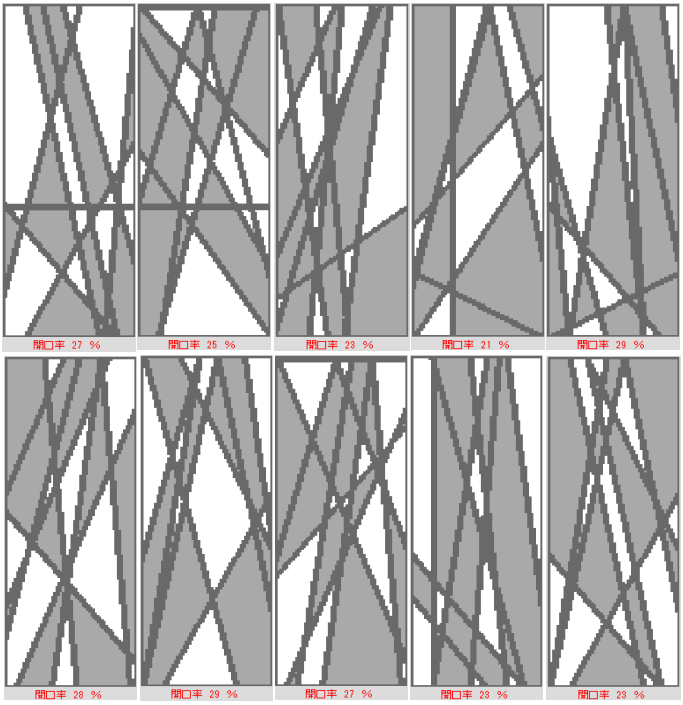


Figure.8 Various examples

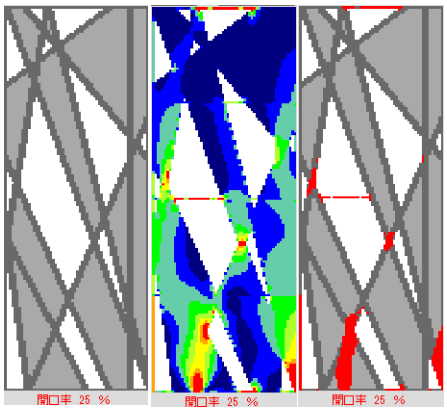


First-generation parent

Selection of design



10th generation parents



Final design

Figure.9 Verification of validity.

Conclusions

Generating various designs is possible by changing the parameters.
This system could not create design in complete agreement with the building in Figure 1, but the generation of facade design was approximately similar. It is possible to generate designs considered with the sensibility of the user using this system.

Future issue

In the future, we aim to generate designs not only on a planar dimension but also in 3D.
Facade design is considered a crucial factor in the indoor environment and surrounding environment, such as heat or light. Therefore, it is necessary to aim at facade design incorporated environmental factors.

References

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