

# Feasibility Computation of the Perimeter Block Housing in Early Design Process

## *A Perimeter Block Housing Design based on Zone Ordinance of Seoul*

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**Abstract.** *X*The goal of this paper is to present the feasibility computing tool for the perimeter block housing design in early design process. Firstly, the paper describes briefly issues of perimeter block housing focusing on block design cases of Seoul. Secondly, constraints and requirements of perimeter block housing are analysed and formulated based on specific zone ordinance and regulation. Thirdly application of half-edge data structure is presented for interconnected geometric problem solving. Fourthly, multi-objective optimization algorithm developed is shortly explained as problem solving method. Finally, feasibility-computing software using Java object oriented programming is developed. This can contribute to the tool development that can generate, optimize, evaluate and visualize perimeter block housings in early phases of design process by providing reliable design solutions for stakeholders.

**Keywords.** *Perimeter block housing; design-constraints; parametric design; multi-objective optimization problem; design support system.*

## INTRODUCTION

Perimeter block housing is one of dominant block configurations in both western (e.g. Amsterdam and Barcelona blocks) and eastern (e.g. Makuhari New Town in Chiba) cities shown in Figure 1. As one of historical block typologies, perimeter block housing has gained many attentions by municipalities, urban planner and developers. For example, compared to high-rise residential buildings (pavilion), it is common to say that it is attractive to municipalities in that it can bring pedestrians dynamic urbane space along the street and make social community in semi-public inner courts among dwellers. For urban planner and developers, not only does it comply with dwellers' various needs,

but also it guarantees high dense mixed development that can maximize the return on investment (ROI). Moreover as confirmed in Martin and March (1972)'s environmental research that examined and compared several archetypal forms in terms of their efficiency in built potential and daylight availability, it is valuable to study perimeter block housings (courtyards) in that land use performance improves with increasing circumference, i.e. courtyard type performs better than pavilion type in general.

Urban town housing is a kind of perimeter block housing that is studied as an urban development model in Seoul. Urban town house in Seoul

is defined as a five to seven stories perimeter block housing based on zone ordinance. One of the reasons why it received interests except for aforementioned merits is that it can escape the monotonous apartment complex development that have been considered most dominant building type while sustaining pre-existing urban structures such as block and road (Kim et al., 2010).

### Research issues

As an architect reflects complicated building law, changes of building code frequently trigger designer's confusion during design process. Furthermore there are many influential factors that decide the block scheme because of variations, for example, in the size and the shape of blocks and of topography. Considered rectilinear-shaped block study is too complicated to apply for this situation. Rejecting conformity such as unified usage of space in a building, mixed use of offices,

dwelling, stores, and etc. into a building is frequently needed. As a consequence, tool development is necessary to minimize the wrong decision-making sprung from insufficient analysis and evaluation. The current prototype tools for urban code tasks with several plots (urban planning scale) mainly concerns pavilions even though it is developed to the practical application level (Donath and Lobos, 2009). Besides there is little effort for the computational tool development that can deal with perimeter block housing design during the initial design stage.

### Purpose

The main purpose is to determine and quantify the factors that influence the shape and size of the final building block of an perimeter block housing to establish the relationships between the client's requirements, the building code constraints, and the architectural practice in the early design stages.

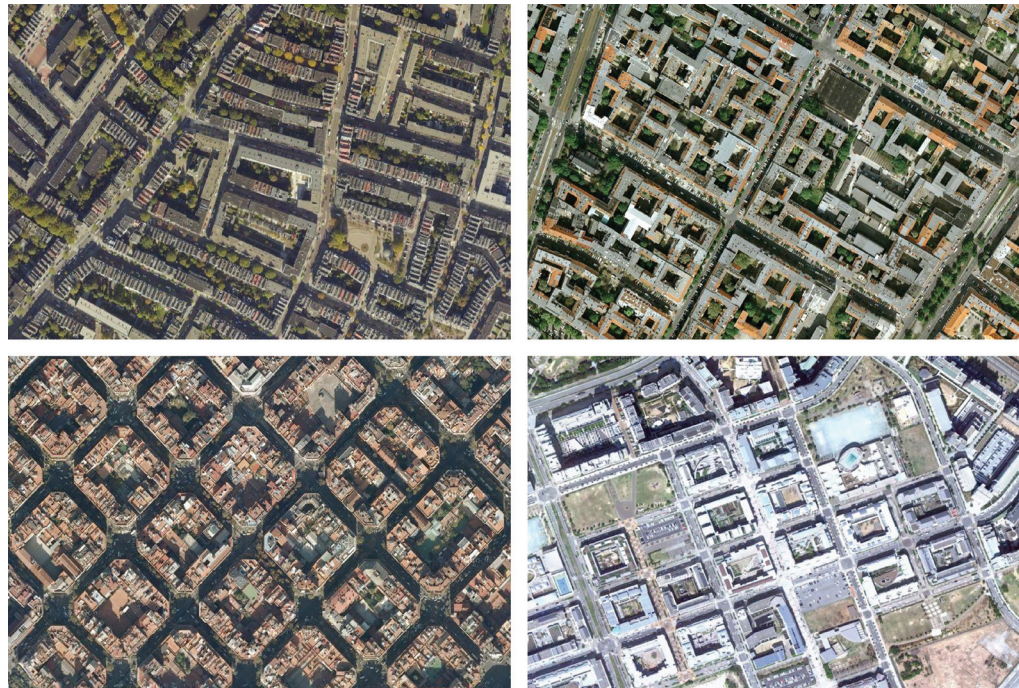


Figure 1  
Aerial images of the perimeter block housing cases. Rotterdam (top-left), Berlin (top-right), Makuhari Baytown, Chiba (bottom-right), and Barcelona (bottom-left).

In the end we will develop a feasibility computing software to support the creation of optimized, parametric allocations of space during periphery block housing design. The tool will be able to suggest feasible design alternatives by flexible alternations of design parameters. Moreover it is independently developed as open-end software that can be used to similar occasions more broadly. In order to accomplish the purpose, constraints and requirements that must be considered with are summarized at first. Next, halfedge data structure that can solve complex geometrical problems of perimeter block housing will be introduced and several important algorithms are invented subsequently. Agent-based modeling with multi-objective optimization will be proposed as well.

## CONSTRAINTS AND REQUIREMENTS

According to the Korean building law and experiences in design practice, in general, an architect must follow more than 10 building codes in the early design stage similar to the research by Donath and Lobos (2009). The rules are a union set from three main domains (law, ordinance, and regulation). Codes listed below are particularly important and defined concisely:

1. Building coverage ratio (BCR) – The ratio of the total floor area inside the building envelope to the size of the land of that location.
2. Floor area ratio (FAR) – The ratio of the total floor area of buildings on a certain location to the size of the land of that location
3. Setback distance – This makes sure that streets and yards are provided more open space and adequate light and air.
4. Building height – This determines the maximum vertical distance allowed between the natural ground level and the highest point on the building.
5. Parking – 1 parking lot per flat. Parking space occupies approximately 27% of the gross floor area when constructed under the ground.
6. Sunlight limitation – Minimum sunshine duration on the winter solstice.

7. Pitch of building – This determines the maximum vertical height of buildings in a site by checking distances among buildings. Distance between neighboring buildings is more than  $0.5H \sim 1.5H$  (mostly  $0.8H$ ). This is used on behalf of the sunlight limitation.
8. Sky exposure plane control or Oblique line limitation – This determines the height of the building by the ratio between perpendicular distance from a building to its neighboring road and the building height.
9. Story height – About 3 meter on average.

## Space Program based on Project Size

There are differences in required space according to the contextual characteristics, the size of the block, and the development approach. When developed as a single block or small-scale project, spaces for neighborhood facility, control office, elderly community hall, etc. must be included. Middle- and large-scale projects necessitate more functional spaces than small-scale project. For example, neighborhood facilities are calculated by multiplying the number of flats and 6 square meters without considering the size of a project. The number and the size of necessary spaces as listed below can be calculated based on regulation as usual.

1. Private – flat, etc.
2. Semi-private – office, shop, etc.
3. Semi-public – control office, elderly community hall, amenity facility, kindergarten, etc.
4. Public – parking lot, basement garage, library, etc.

## DATA STRUCTURE

### Halfedge Data Structure (HDS)

Seeds to construct a basic data structure of the system are lines that representing roads and streets. Lines are manually drawn in the canvas or given from external file. Next step is to find intersections among lines. If a line has  $n$  respective intersection points (nodes) it is composed of  $n+1$  respective line segment. If there is no line segment from a line, this

line is not considered valid because it has no link to other line. As a result, nodes and links are obtained and represented as Halfedge Data Structure (HDS). To construct perimeter blocks, HDS is of importance in representing plane graphs of road (street) system (Brönnimann, 2001). As shown in figure 2, when HDS is constructed properly we can develop several functions that can be used in the system as follows: Firstly, neighboring road segments of one road segment can be pointed. Secondly, neighboring perimeter blocks of one perimeter block can be pointed. Thirdly, two confronting perimeter blocks that are divided by a road segment can be pointed by selecting the road segment. Fourthly, by choosing one corner point, corner-sharing perimeter blocks can be found. Fifthly, surrounding road segments of a perimeter block can be pointed.

### Road segment and perimeter block housing

Data structure of an abstracted road segment is composed of six key attributes: 'start vertex', 'end vertex', 'Block on the left', 'Block on the right', 'number of lanes', and 'width'. The width value of a road segment is coupled with the number of lanes. Once surrounding road segments of a perimeter block are found, it is possible to obtain the bounding polygon of perimeter block by offsetting inwardly and trimming the respective road segments. Buildable polygonal area of a perimeter block is acquired by applying a setback rule to the bounding polygon. Buildable

polygon is the boundary lines of the perimeter block housing in this system.

The case that a PBH contains multiple courtyards is not considered in this study. Hereafter PBH is the housing type that has only one inner courtyard. PBH has two bounding polygons: one is an inner bounding polygon that surrounds PBH's courtyard and the other is an outer bounding polygon that is identical to the building polygon acquired above. An inner bounding polygon is calculated with respect to the given depth of a unit. In figure 3, gray-colored configuration is the footprint of a PBH. Next step is to find units of PBH. By dividing the footprint into bars (into six bars in figure 3) and by subdividing the bars into unit spaces, basic units of PBH is obtained. The units of the PBH are classified as two sorts of space: 'bar space' and corner 'corner space'. Corner space exists at the corners of PBH and bar space exists in the remains of PBH. Clear difference between two spaces is that bar space has two facades, each of which faces opposite direction. Bar space is more advantageous to use natural ventilation system and to put dominant (favorite) apartment unit types than corner space. When subdividing bar space into unit cells, eight occasional rules can be classified based on the angles on each end point in order to get bar space as shown in Figure 3 (a) ~ (h). In case of figure 3 (b), for example, both sides are obtuse angles and two vertical extension lines are stretched from outer line segment to inner line segment in order to build a bar space. Additionally, in case of figure 3 (h),

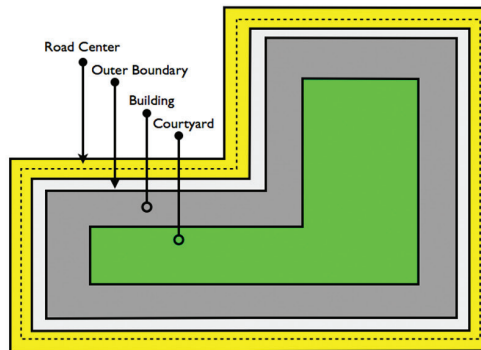
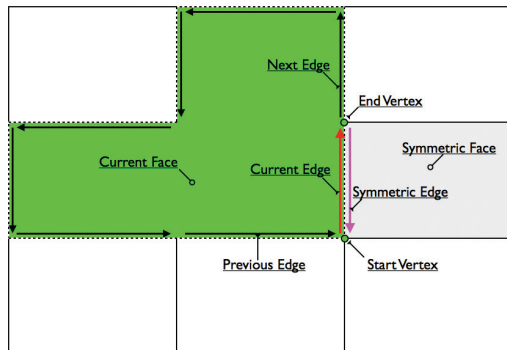


Figure 2  
Halfedge Data Structure (left)  
and perimeter block housing  
scheme (right)

left side is acute angle and right side is obtuse angle that one vertical extension line is stretched from inner line segment to outer line segment and vice versa. Seeds to initiate PBH at early design stage in the system are variables of units, building coverage ratio, floor area ratio, pitch of building, maximum building height, floor height, oblique line limitation, and so on.

## COMPUTATIONAL TOOL

### Agent based modeling

To approach this research from a computational point of view, an agent-based modeling (ABM) is suitable for the periphery block housing design task. The new software is programmed as an independent tool using Java language. Here ABM is composed of decision-making entities called agents (Bonabeau, 2002; Macal and North, 2007). Each agent acts independently according to the rules and execute its pre-programmed behaviors such as repetitive competitive pro-actions and re-actions between agents. As drawn in figure 4, an agent- "PerimeterHousing" – that represents attributes of a building complex in a block is designed to solve problems that are related to physical constraints. Geometric tools by

Schneider and Eberly (2002) are widely applied in order to treat complex geometric issues. Moreover architectural entities of this modeling highly resemble those of IFC (Industry Foundation Classes) architectural domain, which make it possible to interoperate with other BIM software.

### Optimization

Experience of early attempts at the solving process promotes the development of new approaches. Multi-objective optimization algorithm as represented in Figure 5 is designed to manage a PBH project. Genetic Algorithm (GA) that mimics the design process of imaging, presenting, and testing (Zeisel, 1984) is utilized as a design generation and a problem solving strategy. The merit of GA is its possibility to draw feasible solutions that do not violate the constraints while maintaining their diversity (Fonseca and Fleming, 1998; Coello, 2001). It is sometimes possible to deduce unexpected ones that are distinctive. In almost all cases, it is impossible to obtain the best performance across all the objectives concurrently. Hence two series of GA are operated. The one called density fitness function (DFF) is a tool that concerns the overall density in a project. The other

Figure 3  
Boundary subdivision for unit  
generation of a perimeter  
block housing

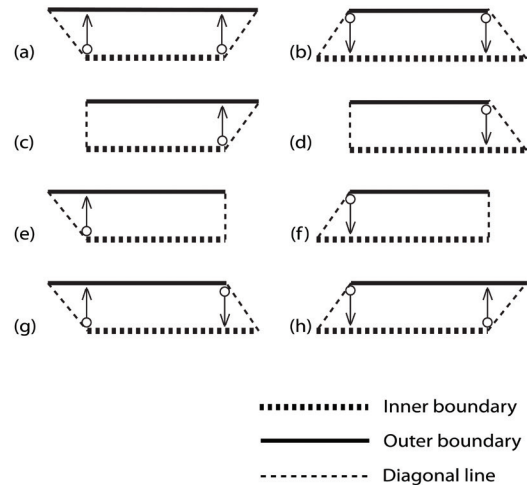
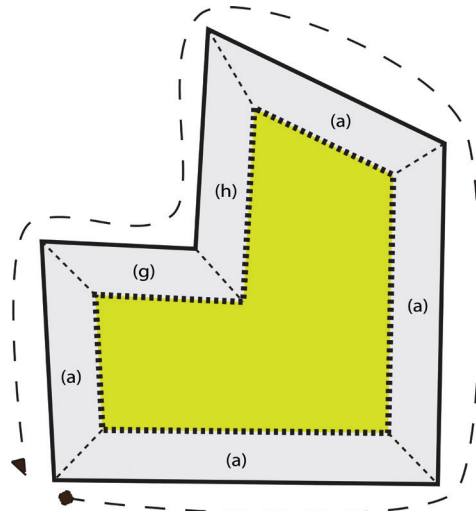
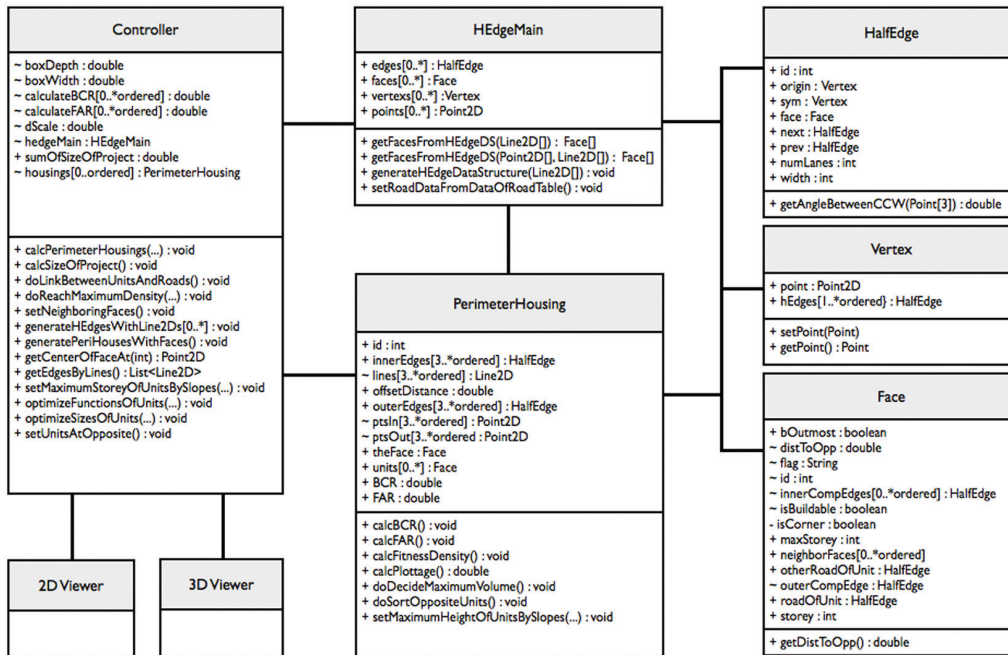




Figure 4  
Agent-based modeling for  
PBH



participates in the functional space allocations according to a space program.

One unified fitness function of a PBH project can calculate a fitness value at each generation by introducing weighted sum fitness functions (Coello, 2001). The rule of DFF is to maximize FAR value within the limitation of a given FAR (gFAR) and to balance various units sizes (small, medium, large, and extra-large) based on specific size parameters (e.g.  $w_1$ ,  $w_2$ ,  $w_3$ , and  $w_4$ ). By using size parameters, we can calculate the optimal sizes (e.g.  $w_1 \times gFAR$ ,  $w_2 \times gFAR$ ,  $w_3 \times gFAR$ , and  $w_4 \times gFAR$ ) of the respective units. If respective areas (e.g. Si, Mi, Li, and XLi) at a generation are obtained, current fitness value for density can be obtained as Equation 1. Other fitness functions adopt that of DFF as well.

$$F_i = (\min(1, S_i / (w_1 \times gFAR)) + \min(1, M_i / (w_2 \times gFAR)) + \min(1, L_i / (w_3 \times gFAR)) + \min(1, X_{Li} / (w_4 \times gFAR))) / 4 \quad (1)$$

The tool can visualize intermediate design steps and final outcome with analysis information. Figure 6 is a screen shot of the feasibility computing software for PBH.

## A CASE STUDY

There are differences in the size of blocks depending to completion period and local context, but mostly 40~60 meters in width and 120~160 meters in depth. Ideally to realize 7 stories urban town house [if two buildings of 21 meter high are planed which are lined with widened incident road of 12 meters width, more than 70 meters is required which is summed up of setback (10M), building depth (30M), and courtyard (21~30M)] that can maximize the feasibility following Korean building code, short edge of a block must be at least more than 60 meters in width for planning and more than 70 meters long for securing enclosure. Figure 7 shows a case design of a PBH in a

Figure 5  
Multi-objective optimization  
algorithms for the perimeter  
block housing

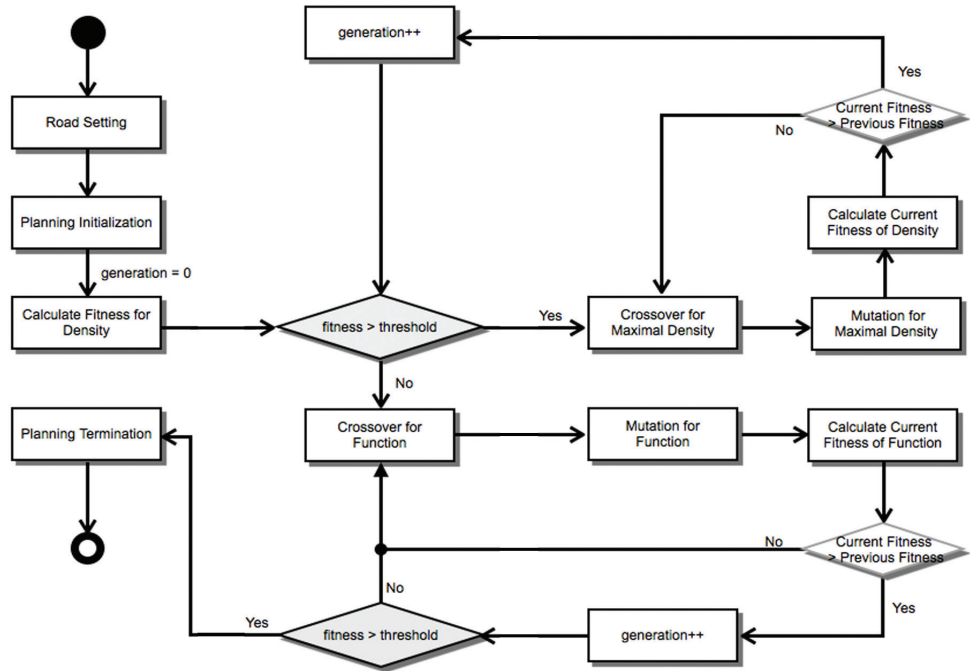
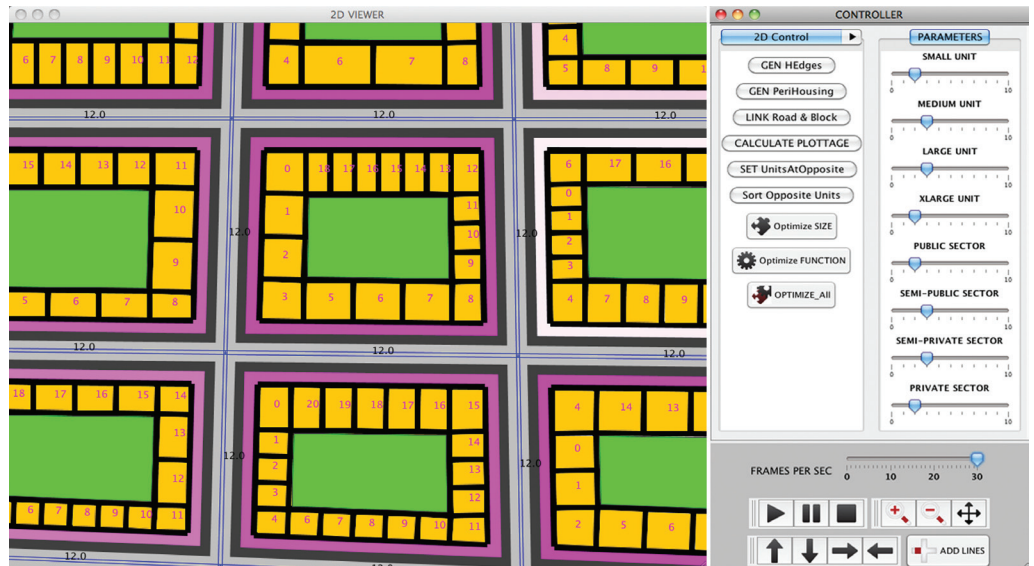


Figure 6  
Feasibility computing software  
for perimeter block housing



test project. When the software initialize the optimization algorithm, a footprint of the PBH is calculated as figure 7 (top-right). Flats are pictorially represented on top-left image of figure 7. Figure 7 (bottom-left) is a final design (FAR: 322%, Fitness: 0.92, gFAR: 350%) of the PBH. Figure 7 (bottom-right) is other final design (FAR: 242%, Fitness: 0.96, gFAR: 250%).

Figure 8 shows two records of fitness values for a PBH project. The starting fitness value of Series 2 is higher than that of Series 1. In order to go to the next generation during the optimization process using GA, a currently calculated fitness

value must be higher than a previous fitness value. Therefore we can expect gradually improved performance of a PBH project without local optimal points. Intervention of a decision maker (DM) is necessary such as setting parameters and threshold as well.

## CONCLUSION

Although the proposed computational tool is originally designed and implemented for periphery block housing in Seoul, there are potentialities to generalize the tool for the application to other similar contexts. During early design stages, designers

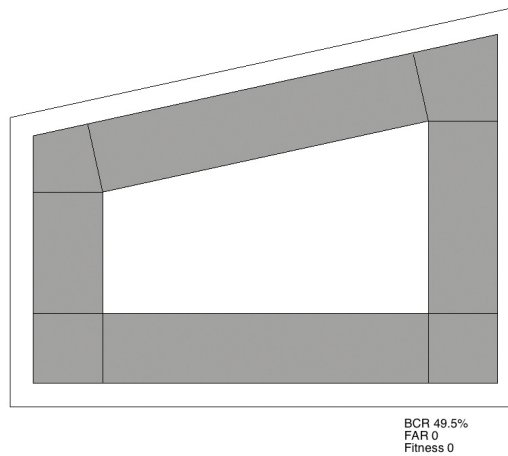
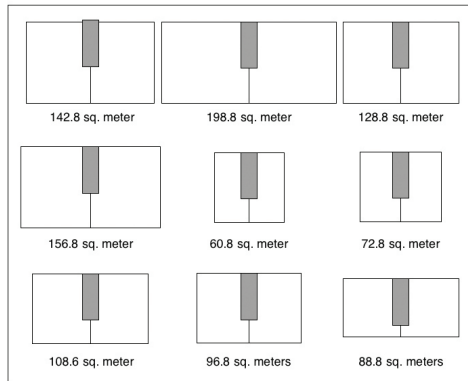


Figure 7  
Results of the case study. Samples of flat variations (top-left), initial footprint of a PBH (top-right), result #1 with fitness value 0.96 (bottom-right), and result #2 with fitness value 0.94 (bottom-left).

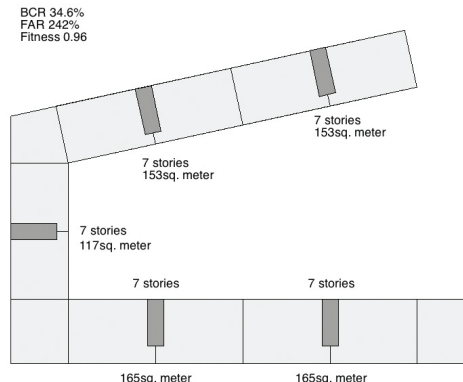
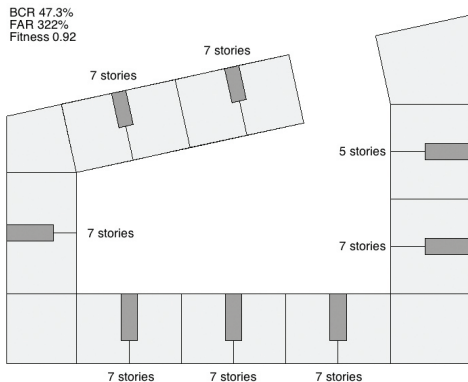
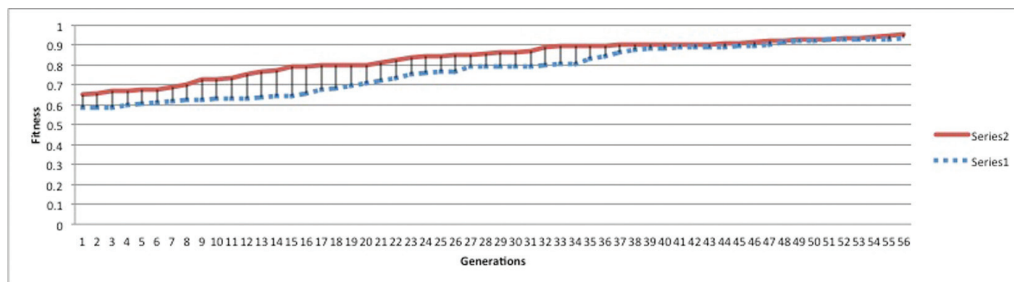




Figure 8  
Two records of fitness values  
for a PBH project



who use the tool to obtain the schematic volumes can minimize the risk of infringing the building codes. Moreover we can positively employ the tool to generate innovative design alternatives. The contributions of this research can be summarized as follows. (1) The variables and constraints of the periphery block housing are formulated based on the building codes and zone ordinances. (2) A computational tool for the feasibility test of periphery block housing design problems helps reduce the working time, increases confidence in the generated solutions. (3) A new design process contributes to the exploration of feasible design spaces in a short period of time. (4) The design data that is gathered from this tool can be exchanged between stakeholders without data loss.

### FUTURE WORKS

The authors are interested in quantitative analysis such as Space Openness Index analysis (Fisher-Gewirtzman et al., 2005) and Sky View Factor analysis (Rodrigues et al., 2005; Osmond, 2010). Java modules for these analyses have been programmed independently; it will be challenging to combine various analyses tool with this study in order to contribute to decision-making process. Moreover, it is necessary to incorporate more design issues such as unit composite types and outdoor environment design into the system.

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### REFERENCES

- Bonabeau, E 2002, 'Agent-based modeling: Methods and techniques for simulating human systems', *Proceedings of the National Academy of Sciences*, 99, pp. 7280-7287.
- Brönnimann, H 2001, 'Designing and Implementing a General Purpose Halfedge Data Structure', In: Brodal, G, Frigioni, D & Marchetti-Spaccamela, A (eds.) *Algorithm Engineering*. Springer Berlin / Heidelberg.
- Coello, CAC 2001, 'A Short Tutorial on Evolutionary Multiobjective Optimization', *Lecture Notes in Computer Science: Evolutionary Multi-Criterion Optimization*.
- Donath, D & Lobos, D 2009, 'Plausibility in Early Stages of Architectural Design: A New Tool for High-Rise Residential Buildings', *Tsinghua Science & Technology*, 14, pp. 327-332.
- Fisher-Gewirtzman, D, Shach-Pinsly, D, Wagner, IA & Burt, M 2005, 'View-oriented three-dimensional visual analysis models for the urban environment', *Urban Des Int*, 10, pp. 23-37.
- Fonseca, CM & Fleming, PJ 1998, 'Multiobjective optimization and multiple constraint handling with evolutionary algorithms. I. A unified formulation', *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on*, 28, pp. 26-37.
- Kim, D-N, Lim, H-J & Lee, S-C 2010, 'Study on the Development of the Block Unit Development Model and the Implementation Scheme with Adoption by the Urban Town-House', *Journal Of AIK*, 26, pp. 25-34.

- Macal, CM & North, MJ. 2007, 'Agent-based modeling and simulation: desktop ABMS', *Proceedings of the 39th conference on Winter simulation*, Washington D.C., IEEE Press, pp. 95-106.
- Martin, L & March, L 1972, *Urban Space and Structures*, UK, Cambridge University Press.
- Osmond, P 2010, 'Hemispherical Photography as a Tool for Urban Sustainability Evaluation and Design', *OIDA International Journal of Sustainable Development*, Vol. 1, No. 9, pp. 63-74, 2010.
- Rodrigues, D, Souza, L & Mendes, J 2005, 'Enhancing 3DSkyView Extension Performance', In: Leeuwen, JP & Timmermans, HJP (eds.) *Recent Advances in Design and Decision Support Systems in Architecture and Urban Planning*. Springer Netherlands.
- Schneider, PJ & Eberly, D 2002, *Geometric Tools for Computer Graphics*, Elsevier Science Inc.
- Zeisel, J 1984, *Inquiry by design, Tools for Environment-Behaviour Research*, Cambridge University Press.