The 6th International Conference on Construction Engineering and Project Management (ICCEPM 2015)
Oct. 11 (Sun) ~ 14 (Wed) 2015 • Paradise Hotel Busan • Busan, Korea
www.iccepm2015.org

A comparison of three multi-objective evolutionary algorithms for optimal building design

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Abstract: Recently, Multi-Objective Optimization of design elements is an important issue in building design. Design variables that considering the specificities of the different environments should use the appropriate algorithm on optimization process. The purpose of this study is to compare and analyze the optimal solution using three evolutionary algorithms and energy modeling simulation. This paper consists of three steps: i)Developing three evolutionary algorithm model for optimization of design elements ; ii)Conducting Multi-Objective Optimization based on the developed model ; iii)Conducting comparative analysis of the optimal solution from each of the algorithms. Including Non-dominated Sorted Genetic Algorithm (NSGA-II), Multi-Objective Particle Swarm Optimization (MOPSO) and Random Search were used for optimization. Each algorithm showed similar range of result data. However, the execution speed of the optimization using the algorithm was shown a difference. NSGA-II showed the fastest execution speed. Moreover, the most optimal solution distribution is derived from NSGA-II.

Keywords: Multi-Objective Optimization, Evolutionary Algorithm, Meta-Heuristic, Genetic Algorithm, Optimal Design.

I. INTRODUCTION

Recently, many countries establish policy that affects the green building design. It plans to solve environmental problems during the life cycle of buildings [1]. Accordingly, studies have increased to find optimal components in building design phase [2]. As a result, a lot of programs have been developed. Most optimization simulation programs are based on evolutionary algorithms. Generally, GenOpt is composed as Particle Swarm Optimization (PSO) [3].

Design variables considering the specificities of the different environments should use the appropriate optimization algorithm. The purpose of this study is to find the optimal design elements in building design phase using a variety of evolutionary algorithms and compare the efficiency and characteristics of the respective algorithms.

II. METHODOLOGY

A. Optimization Model and Algorithms

In this study, optimization models for solving the trade-off problem in design phase are developed. Energy modeling simulation of a building is used in the EnergyPlus-v8.1 (EP) [4]. To connect EP with developed Multi-Objective Optimization (MOO) model, the MOEA Framework-2.4 based Java Language is used [5]. MOEA Framework-2.4 is made of 26 algorithms to apply optimization model easily. As shown in Fig. 1, flowchart of optimization model has been developed for this study.

Selected population-based algorithms (P-meta) are Non-dominated Sorted Genetic Algorithm (NSGA-II), Multi-Objective Particle Swarm Optimization (MOPSO) and Random Search in this study. NSGA-II is one of the most widely used algorithms in the MOO. This algorithm is based on Darwin's evolutionary theory. After generating the initial population, it can search for optimal solution through crossover and mutation [6]. MOPSO is developed by focusing on crowd to follow foods. Lastly, Random Search detect for the optimal solution by using random generating population. Random Search is easy to implement but difficult to find optimal solution.

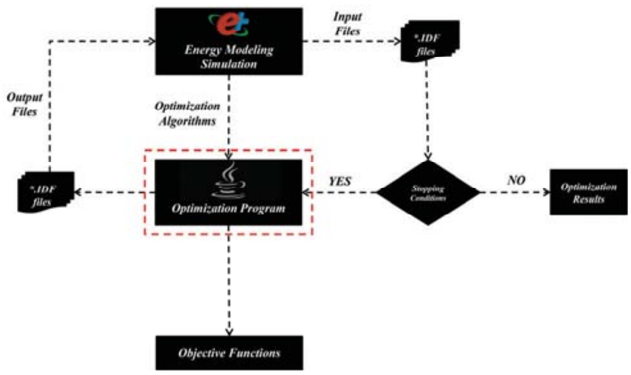

Figure 1. Optimization model flowchart

B. Design Variables

Design variables for optimization are 26 types of double glazing. In intermediate space, gas is also selected as Argon and Air. In order to obtain detailed double glazing specification, International Glazing Database was referred.

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TABLE I
DESIGN VARIABLES

Window Type	Intermediate Space
$X_1 \sim X_{26}$ (Double glazing)	$X_{27} \sim X_{30}$ (Argon and Air)

C. Objective Functions

In this study, objective functions are annual energy use and Predicted Percentage of Dissatisfied (PPD). This study is looking for ways to minimize the objective functions with the optimal window design.

$$f_1 = PPD(\%) \quad (1)$$

$$f_2 = EnergyUse(\,kWh\,/\,Year\,) \quad (2)$$

$$MinF(\,X\,) = F(\,f_1, f_2\,) \quad (3)$$

III. CASE STUDY

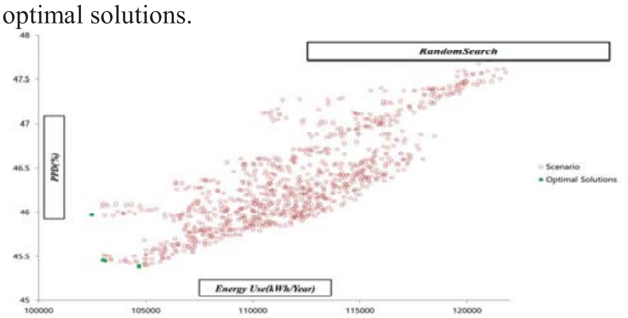
The target building is an elementary education facility that is located in Seoul, Republic of Korea. Window is installed on 90 places of the outer wall. And the number of occupants is assumed to be 690 people.

IV. OPTIMIZATION RESULTS

TABLE II
OPTIMIZATION RESULTS

	Random Search	NSGA-II	MOPSO
Setting value	Population Size : 50 Iteration : 1000	Population Size : 50 Mutation rate: 0.1 Crossover rate : 0.9 Iteration : 1000	Population Size : 50 Mutation Probability : 0.1 Iteration : 1000
Elapsed time	19h 16m 46s	19h 09m 13s	19h 52m 33s

The shortest running time is NSGA-II; 19 hours 9 minutes 13 seconds. This simulator as a single thread did not use the parallel programming. Random Search is recorded for 19hours 16 minutes 46 seconds. Finally MOPSO shows the slowest performance time is 19 hours 52 minutes 33 seconds. The process of finding the optimal solution is shown in Fig. 2. Population of Random Search is distributed sporadically. Except for the Random Search, MOPSO and NSGA-II is similar or the same in finding optimal solutions.



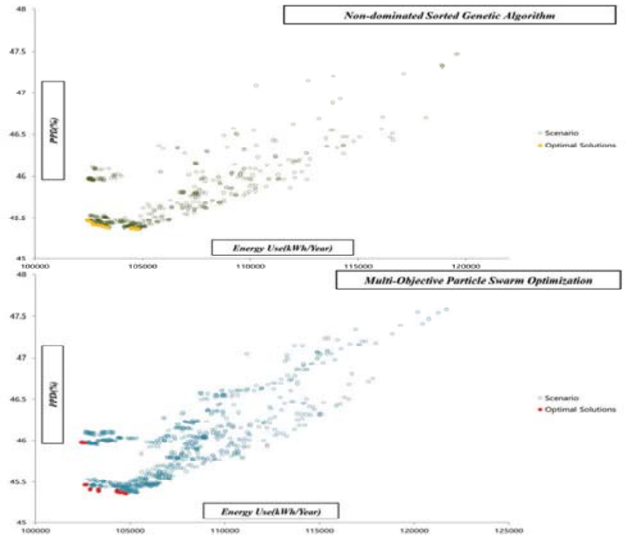


Figure 2. Results of three algorithms optimization

V. CONCLUSION

This paper aims to compare three MOO to find optimal building elements in design phase. This study proceed in three steps: i) developing three evolutionary algorithm model for optimization of design elements; ii) conducting Multi-Objective Optimization based on the developed model; and iii) conducting comparative analysis of the optimal solution from each of the algorithms. Limitation of this study is focused only on the comparison of the algorithms. It did not apply a lot of factors such as between time and cost trade-off problem at a construction site.

Future research will apply the trade-off problem which can be used in the actual construction site with comparison between algorithms.

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP; Ministry of Science, ICT & Future Planning) (No.NRF-2015R1A2A1A05001657).

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