OPTIMIZATION IN THE ARCHITECTURAL PRACTICE

An International Survey

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Abstract. For several years great effort has been devoted to the study of Architectural Design Optimization (ADO). However, although in the recent years ADO has attracted much attention from academia, optimization methods and tools have had a limited influence on the architectural profession. The aim of the study is to reveal users’ expectations from the optimization tools and define limitations preventing wide-spread adaptation of the optimization solvers in the architectural practice. The paper presents the results of the survey "Optimization in the architectural practice" conducted between December 2015 and February 2016 on 165 architectural trainees and practising architects from 34 countries. The results show that there is a need for an interactive multi-objective optimization tool, as 78% respondents declared that a multi-objective optimization is more necessary in their practice than a single objective one and 91% of them acknowledged the need for choice of promising solutions during optimization process. Finally, it has been found that daylight, structure and geometry are three top factors which architects are interested in optimizing.

Keywords. Architectural Design Optimization; Optimization Techniques; Generic Solvers; Multi-criteria Decision Making.
1. Introduction

Today’s challenges in the architectural industry are centred around energy saving, cost-effectiveness, and improving safety and occupant comfort. To address so many different challenges computational optimization is a must. In order to analyze and solve more and more complex design problems Artificial Intelligence is adopted to the architectural field. Evolutionary Algorithms (Rutten 2013; Vierlinger 2013), Swarm Intelligence (Cichocka et al. 2015), Artificial Neural Networks and other biologically inspired techniques are employed to support architects in discovering high-performing design solutions. Although optimization plays a vital role in the recent architectural research, optimization techniques have very barely influenced the architectural profession in contrast to the engineering design (Flager & Haymaker 2009). The time intensity and complexity of architectural design are considered as two potential reasons for the lack of the popularity of the optimization methods among architects (Wortmann et al. 2015). In ADO evaluations of the robustness of the optimization methods often are not very rigorous when compared to the mathematical optimization field. Nevertheless, optimization techniques for ADO have been being evaluated by several researchers by means of the comparisons of the different optimization techniques using quantitative benchmark problems (Wortmann & Nannicini 2016; Evins 2013; Aly & Nassar 2013; Cichocka et al. 2015). It is believed that employing the appropriate optimization method is crucial in achieving the optimal solution, especially in complex design problems (Wortmann & Nannicini 2016). However, we argue that there are other barriers that prevent practitioners from achieving optimal design solutions in their practice. The main aim of this paper is to reveal the possible improvements in the implementations of the black-box optimization algorithms in the generic solvers based on the practitioners’ experience and needs. The secondary objective is to verify if there are other reasons why optimization is not commonly used in the architectural practice apart from the computational effectiveness of the employed optimization algorithms and the complexity of the architectural design problems. In this paper, we explore the users’ expectations and the limitations of the optimization tools from the practitioners’ point of view. The results could aid the creation of a user-friendly and robust optimization application for architects and accelerate popularization of the ADO among practitioners. Optimized real-world design problems in architecture mean comfortable, safe, cost- and energy-effective built environment. The expectations from practitioners concerning number of objectives, architectural features to be optimized and the need of education in ADO are examined and directions of the potential development of the computational optimization solvers are sketched. In the first paragraph the search strategy and criteria are presented. The second section reports on the achieved the results, which are discussed in the Discussion and Conclusion paragraphs.

2. Search Strategy and Criteria

165 architectural trainees and practitioners have participated in the survey with the professional experience ranging between 1 and 46 years (including architectural studies). This research was confidential. Neither the participants’ names nor any information that would allow identification was included in the research survey.
The notes or transcript of the interview were read only by us. The interview transcripts, summaries and any recordings will be kept securely and destroyed 3 years after the research ends. The research conforms to the University’s Treaty of Waitangi Statute by valuing the Tiriti o Waitangi, rangatiratanga (leadership), manaakitanga (the generous fostering of knowledge), kaitiakitanga (responsibility for, and guardianship of, knowledge), whai matauranga (intellectual curiosity), whanaungatanga (collaboration and collectiveness) and akoranga (collective responsibility for learning). Survey was conducted in the on-line form and was emailed to the target groups (architects and designers) and published in the research groups. The recipients of the link to the on-line survey form had no obligation to fill it and their participation was of voluntary nature. The participants could also quit the survey at any moment. Only submitted forms were recorded. No feedback was provided to the participants. The survey was approved by the Victoria University of Wellington Human Ethics Committee with the Ethics Approval number 223779.

3. Survey Questions and Results

The survey was composed from 13 questions: deterministic type yes/no, multiple choice and open questions. The first two questions were supposed to describe the participants based on their years of professional experience and the country where the school, university, company or organization which they were mostly associated with is based.

3.0.1. Q1 How many years have you been in the architectural practice? (open question, numerical input)

Most of the responders had the professional experience ranging between 5-10 years. The least experienced surveyee was the first year student and the most experienced one had 46 years of professional carrier.

3.0.2. Q2 In which country is the school, university, company or organization you are mostly associated with based? (open question, string input)

The responders’ school, university, company or organization which they are mostly associated with are based in 34 countries with majority based in Germany, Poland, Italy and New Zealand. All countries which the participants felt professionally affiliated with and corresponding number of answers are presented below (figure 1).

3.0.3. Q3 Do you use any parametric design software packages in your practice? e.g. Grasshopper3D, Dynamo for Autodesk Revit, GenerativeComponents (single choice: yes or no)

- yes (83.0%)
- no (17.0%)
Figure 1. The countries which respondents associate their professional carrier with. n/a means that the responder did not indicate any country.

If yes was selected in the Q3 question the surveyee was asked to select the software that she or he used most often with only one choice possible (single choice).

- Dynamo for Autodesk Revit (6.6%)
- Grasshopper3D for Rhinoceros3D (89.9%)
- GenerativeComponents for Microstation (0.0%)
- Digital Project (0.7%)
- other (2.9%)

83% of the survey’s participants use parametric design software packages e.g. Grasshopper3D, Dynamo for Autodesk Revit, GenerativeComponents in their practice. As presented in the figure 2, Grasshopper3D for Rhinoceros3D is the most popular design platform. This result confirms that Grasshopper3D has gained most popularity in academia and among professionals, leaving the other parametric software applications behind (Vierlinger 2013; Martyn 2009).
3.0.4. Q4 Do you use any scripting tools in your design practice? (single choice: yes or no)

- yes (57.6%)
- no (42.4%)

If yes was selected in the Q4 question the surveyee was asked to select the scripting or programming languages that she or he used from the list below with multiple choice possible.

- Processing (26.2%)
- RhinoScript in Rhinoceros3D (13.5%)
- C sharp in Grasshopper3D (12.7%)
- Visual Basic in Grasshopper3D (11.1%)
- Python in Grasshopper3D (28.6%)
- Python Script in Blender (0.7%)
- MEL in Autodesk Maya (3.2%)
- other (4.0%)

57.6% of the surveyed trainees and partitioning architects declared to use scripting tools in their professional activities. Python for Grasshopper3D and Processing reached the greatest popularity among following programming languages: Processing, Rhinoscript in Rhinoceros3D, Visual Basic, C sharp and Python in Grasshopper3D, Python Script in Blender and MEL in Autodesk Maya. Rhinoscript in Rhinoceros3D and C sharp in Grasshopper3D were selected almost the same number of times and they are second commonly used programming languages in design practice. 37% of respondents using scripting tools in his/her practice declared to use more than one programming language (35 surveyees).
3.0.5. **Q5 Would you like to optimize your designs without the need to produce scripts?** (single choice: yes or no)

- Yes (86.8%)
- No (13.2%)

87% architectural trainees and practitioners would like to optimize designs without the need to produce scripts.

3.0.6. **Q6 Would you commonly optimize one feature of your design or many features at once?** (single choice)

- one feature (single objective optimization) (21.7%)
- many features (multi-objective optimization) (78.3%)

78.3% of respondents have stated that most commonly they would optimize many design features at once.
3.0.7. **Q7 Which aspects of your design would you like to optimize? (multiple choice)**

- daylight availability
- circulation
- layouts
- views
- structure
- general shape for building code/regulations
- other

![Figure 4. Architectural features selected by respondents to be optimized.](image)

3.0.8. **Q8 In the optimization process would you prefer to: (single choice)**

- run it with default settings and do not spend much time on tuning the settings (15.2%)
- spend some time to tune a few settings provided I understand how they influence the accuracy and time of the optimization process (30.5%)
- have the possibility of changing every parameter in the optimizer in order to have full control over the process (54.3%)

3.0.9. **Q9 Would you like to influence outcomes by choosing promising designs during this optimization? (single choice: yes or no)**

- Yes 90.7%
- No 9.3%

91% surveyed architects would like to influence outcomes by choosing promising designs during optimization process.
3.0.10. Q10 As an optimization outcome would you prefer to get: (single choice)

- one best design solution (17.8%)
- a few high-quality solutions (82.2%)

If yes was selected in the Q10 question the surveyee was asked to specify how many solutions she or he would like to compare. 70% of the survey participants would like to have a choice between 3 and 5 optimized design options, and 17% of respondees would prefer the choice between 6 and 10. It has to be mentioned here, that most probably the responders expect different solutions to be compared. The diversity of the optimized solutions directly relies on the number of objectives and the size of the domain of the given parameters. Summing up, it is evident that the vast majority of the surveyed architects would like to have a choice between 3 and 10 optimized design options.

3.0.11. Q11 In the early design stage, how long could you wait for the solution or the catalogue of solutions from the optimization process? (single choice)

- up to 5 minutes (29.6%)
- up to 1 hour (36.0%)
- up to 1 day (31.2%)
- up to 1 week (3.2%)

Figure 5. The maximum amount of time that participant would like to wait for the answer from the optimization process.

Architectural designers are not unanimous in the potential time cost which they could pay for achieving optimized design solution(s). In general optimization processes that could take more than one day would be avoided in practice.

3.0.12. Q12 Would you like to understand why an optimizer selected the presented solution(s) over other alternatives? (single choice: yes or no)

- Yes 92.8%
No 7.2%

92.8% of the architectural designers would like to understand why the solver selects the particular solution over alternatives.

3.0.13. Q13 Could you describe any architectural design problem you have ever come across, that you wanted to solve or optimize with computational optimization tools? Describe the aim that you wanted to achieve, the constraints of the problem and how you solved the problem.

This question revealed some of the real-world problems that have been already encountered in the architectural practice. Respondents among others enumerated following problems: multi-criteria problems in designing shading devices (membranes or louvers) aiming at minimization of the material use, with solar radiation analysis and structural and manufacturing constraints; rationalization of paneling systems of the complex surfaces aiming at planarization of elements and adjusting them to the fabrication constraints; structural form-finding with multiple factors determining form, optimization of the shapes of trusses and cross sections of structural elements; layout optimization and block programming based on the user defined adjacencies and user-friendliness; managing thermal and electrical capacity in accordance to building shape and occupancy. Participants also mentioned topics that would be difficult to solve with numerical optimization techniques like material aging or predicting the future.

4. Discussion

The results of the survey confirmed the previous researchers’ statements (Martyn 2009; Vierlinger 2013) that Grasshopper3D for Rhinoceros3D is the most often parametric software selected by architects for use. Dynamo for Autodesk Revit has been indicated as the second most popular visual programming design platform. The results obtained from the survey have indicated directions of the development of computational optimization methods that would fit to the needs of practitioners. Nevertheless, it stays unclear if the computational expensiveness is the crucial factor that prevents architects from using optimization tools. It has also to be underlined that only people interested in the latest design techniques and optimization in architectural design responded to the survey. The group of surveyors included mostly young practitioners up to 5 years after graduation, therefore brought research questions stay unanswered from the older and more experienced generation of architects.

5. Conclusion

From the research that has been undertaken, it can be concluded, that multi-objective optimization techniques/tools are more necessary in the architectural practice than single objective ones. Moreover, it has been demonstrated that majority of practising architects (93%) would like to understand the underlying optimization procedures and 54% would prefer to have full control over optimization process, thus intuitive and easy to-understand optimization algorithm would be more suitable in the architectural practice. Furthermore, the interactive optimiza-
tion methods and ‘human in the loop’ approach seem the most appropriate, as almost all of surveyees (91%) would like to select promising designs during the optimization process. Finally, this paper has clearly shown that daylight, structure and geometry are the three top features that architects are interested in optimizing. The obtained results might help in improving technological, implementational and educational aspects of optimization processes in the building industry. Consequently, robust optimization processes could significantly reduce carbon-footprint, reduce the material use and increase the energy-efficiency of the future architecture.

References