Sun shading of the future

A next generation workflow for applying the performative computational architecture framework to sun shading design, based on an example sun shading system for high-rise office buildings with all-glass exteriors in tropical climates optimised on visual and thermal comfort

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Reflection

Relationship between research & design

In order to design the sun shading of the future, it is important to gain insight in what defines the performance of the sun shading. Ultimately, the main purpose of shading systems in building design is to enhance the comfort of the occupants. When this is done as efficient as possible, the use of energy consuming HVAC systems to artificially achieve a state of comfort can be limited as much as possible, resulting in more sustainable buildings.
In the first phase of the graduation, leading up to the P2 presentation, lots of literature research was done to define metrics qualifying the levels of thermal and visual comfort. These metrics will be used in the design process to evaluate the performance of various shading systems. Based on the findings of this research two design tasks were to be completed.
The first design task involved selecting and adapting a sun shading system. This was done based on typologies defined by literature sources in combination with their suitability for the specific scope of this research. This resulted in selecting a fixed shading system; the egg-crate system, and placing it within the cavity of a double skin façade, in order to adapt it to fit the requirements of the scope. The next step within this design task was the parametrization of the concept, in order to be integrated in the PCA method. After applying this sun shading system to an example building floorplan, this will serve as an example case to explore how the PCA method can contribute to improving the performance of the selected shading system
The second design task involved developing a specific PCA methodology. Firstly, the fundamentals of the PCA method in general were research in literature. Thereafter, based on literature findings and case studies, a typology categorization for PCA processes was developed. This helped designing the PCA workflow for the performance evaluation and optimization phase. The workflow is tested using the example case defined in the first design task. Based on these results, various questions about the performance of the optimized version of the selected example can be answered. In addition, the results for the example case can be used to asses the feasibility of the developed PCA methodology itself as well. This resulted in two proposals for further improvement of the researched PCA methodology itself.

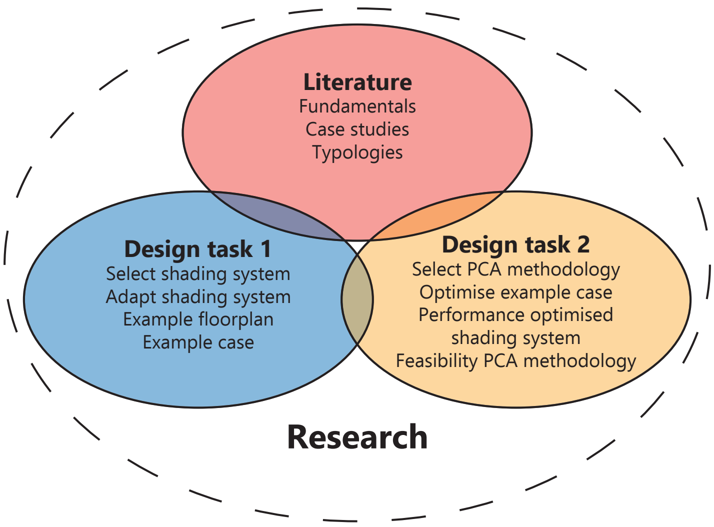

Figure 1. *Diagram: relation between research & design (by author)*

Relationship between the topic, building technology track & Msc program

In my opinion, this graduation topic covers the core of the building technology master track; Using technology to design better buildings. In this case, better means more comfortable visual and thermal indoor environments achieved in a more sustainable way. The technology used in this case to achieve this improvement on comfort is the PCA method.
I think one of the main purpose of graduates of this master track is to form a bridge between the novelty developments of the scientific research realm and the architectural practice realm. Before graduating, I gained some practical experience working in multiple architecture offices. During these experiences I noticed there is a lot of interest in the development of these parametric design tools in relation to healthier buildings. However, there also appears to be a lack of knowledge about how to properly use these tools to create architecture. This research has shown the current methodology for implementing the PCA method can still be improved. As a future graduate, I hope be a part of this development and to be able to use it's potential to help designing the buildings of the future.

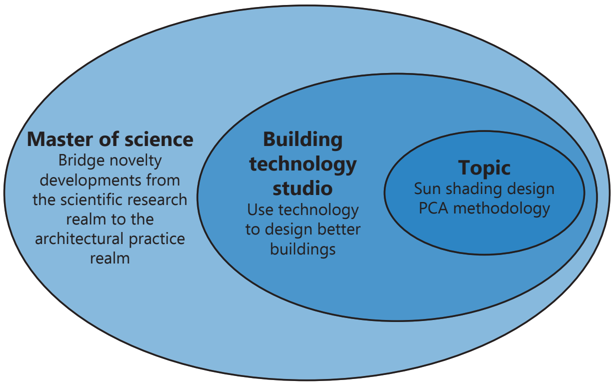

Figure 2. *Diagram: relation between topic, studio & master program (by author)*

Research method & approach in relation to BT inquiry & scientific relevance

In my graduation plan I described multiple methods used for this project in chronological order. The first one is the literature research method. This consisted of two parts, the first being the fundamental theory part (about visual comfort, thermal comfort, the PCA process and shading requirements for high-rise.) And the second part, the state-of-the-art review (about case studies and typology on PCA use in sun shading and sun shading in high-rise. The relevance of this method is to assemble all required information for the design tasks.
The second selection method is the selection method, with the goal of selecting the most promising sun shading concept for buildings within the scope. At the time of writing the graduation plan, this method was envisioned to use three steps;

1. Cross-referencing typologies; building two databases, one with parametrically design shading systems, the other with shading systems used in high-rise. The two databases would be cross-referenced with the other scopes of this graduating project
2. Out-of-the-box brainstorm; thinking about possibilities for adapting other shading systems to fit the criteria.
3. Literature review findings; reflect the finding to literature reviews

However, after reconsideration, the order of those three steps was changed to better fit the building technology studio methodical line of inquiry; start at findings in literature findings and work from there. Although the selected shading system is still open for interpretation, the findings in literature helped to substantiate the choice for the egg-crate system in a double skin cavity, by proving its potential for the specific scope of the high-rise office building with all-glass exterior in tropic climates.

The third method is the PCA method, also consisting of three steps; form-finding, performance evaluation and optimization. I did have some previous knowledge about this method, but researching the literature on this topic definitely put things better in perspective. Within the building physics track, a common part of the methodical line of inquiry is to base the specific choice of PCA workflow on precedences. The specific PCA workflow was developed to meet the requirements of this specific case study. As a concluding part, the research gives two proposals to further improve this workflow itself as well.

The fourth method used in this research is the comparison method. This method is used to assess the performance of the selected shading system, optimized using the PCA method, in relation to different alternatives and climates. The graphic representation of the methodology has been changed in between P2 and P4, but the methodology itself remained the same; define shading alternatives, run simulations and compare the presentation on comfort metrics.

The fifth and final method is the exploration method. Originally this phase of the research was envisioned as rerunning the PCA cycle in order to make sure the selected option is actually the best option. However, during the research, the completion of this phase was revised, based on new insights. Being open to adapt the research methodology when preliminary results indicate this might lead to better results is also in line with the studio's methodical line of inquiry. During the research, multiple analysis techniques for optimization techniques where discovered, which have shown to be of value in precedences. Therefore, the step of interpretation and analysis was added to the exploration method. Conclusions derived from these analyses have also resulted in a feedback loop to the PCA methodology itself. In addition, steps for assessing the architectural performance where added as well. Originally this step was neglected in the exploration method, but precedences showed the importance of this assessment in making the final selection for a desirable design. In order to do so, two steps where added to the methodology scheme; automated physical model making and automated VR rendering.

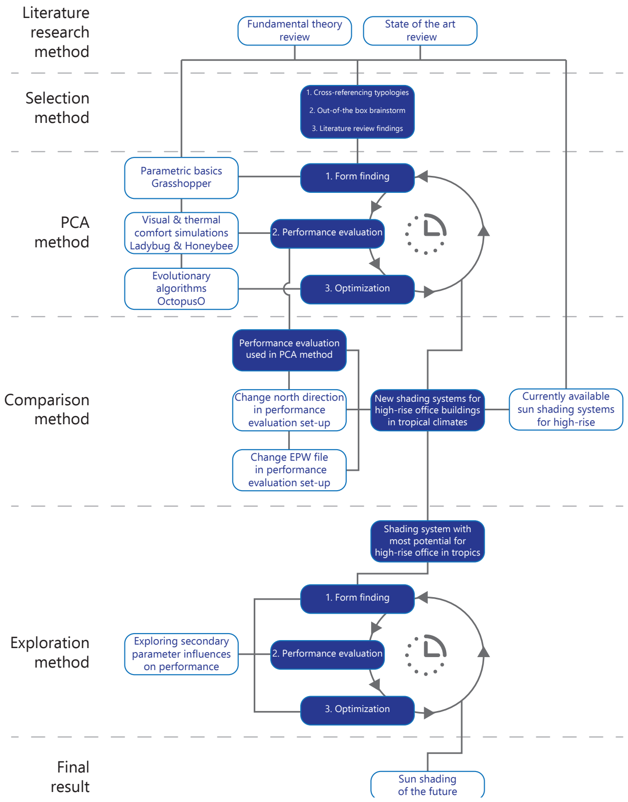

Figure 3. *Diagram: research methodology at P2 (by author)*

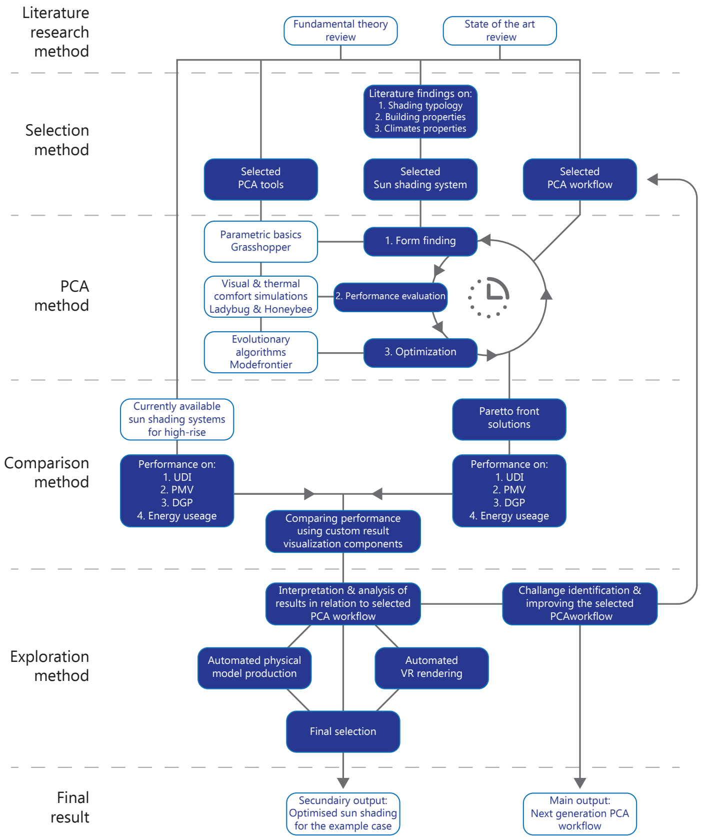

Figure 4. *Diagram: research methodology at P4 (by author)*

The research in wider frameworks & transferability

As stated previously, I noticed an increasing demand for the use of parametric design tools in the professional field. In combination with the observed lack of knowledge within the professional framework, the graduation project fits neatly in a wider professional framework.
Secondly, this graduation project contributes to the design of more healthy and sustainable buildings. With phenomena such as global warming and fossil fuels running out, the need for more healthy and sustainable buildings will become ever larger over time. In the meantime, the demands for visual and thermal comforts will most likely increase in the future, because people have a tendency to become accustomed to luxury. In addition, contemporary trends in architecture such as the all-glass exterior makes the challenge of realizing these comfortable buildings in a tropic climate even harder. Since this research offers a potential solution to the challenges resulting from these trends, it fits in the wider social framework.
With regard to the scientific framework, the topic links to an ongoing scientific field with is currently increasing in popularity due to its high potential for architectural designers. Within the boundaries of the contemporary PCA workflow, the research identified the main bottle neck to be the disability to utilize the full potential of the grid. In addition, the research proposed an improvement of the selected workflow. When this challenge can be overcome, it might result in a big leap forward in the state-of-the-art on implementing the PCA process for sun shading design.
The secondary goal of this graduation project would be a system that will be actually applicable in practice. In this context, that means the parametric script will be able to generate an optimal sun shading geometry for every building perimeter shape, across different locations with tropical climates. Since the comparison method showed the egg-crate shading does perform better than some alternatives, the concept might have potential to be implied in practice. Multiple design decisions have been made based on current trends in architecture and the constructibility of the shading system, further increasing the transferability to actual architectural practice.

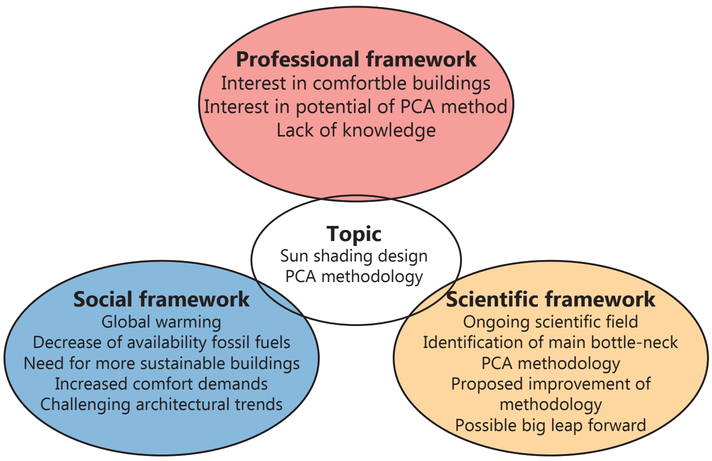

Figure 5. *Diagram: relation between topic, professional, social & scientific framework (by author)*

Ethical issues & dilemmas

The first encountered issue was involving the argumentation for the selection of a shading system. Unsuccessfully, the research tried to identify the best shading system. After reconsideration this goal was classified as unfeasible and the research shifted focus to selecting a shading system with proved potential. After this was found in the form of the egg-crate system, the shading served as a valid example. This still resulted in valuable research results, but due to scoping the research on the egg-crate system, these results cannot be interpreted as comprehensive for all available sun shading systems.

Another issue involved translating the comfort metrics to objectives. With regard to the PCA workflow, it is preferred to combine comfort metrics into a single annual value. For the UDI this was completed relatively easily, by using the UDI (mod-75). However, the PMV score refers to an hourly result by definition. Literature showed no predefined methodology for combining this to an annual data. First an approach similar to the UDI was proposed, but based on preliminary results this was later changed to a sum of the annual exceedance of the PMV comfort domain. Even though this combined PMV score proved to give insight in the performance on thermal comfort, the methodology for combining the hourly values to the annual score is not supported by literature.
Perhaps the biggest dilemma in this research was how to deal with the limitations running ModeFRONTIER in combination with Ladybug and Honeybee. This semester, the faculty's ICT staff tried to integrate ModeFRONTIER in the BK Renderfarm. This was successful for other integrations such as Matlab, but unfortunately without success for the case of Ladybug and Honeybee integration, due to technical limitations. After losing some valuable time by awaiting these developments in vain, the decision was made to run the simulations over the weekend on three computers in the VR lab. Like stated before various times, this resulted in insufficient data to actually identify the Pareto front optimal solutions. The big dilemma at this stage involved the choice of continuing with the current workflow and reserving more time for the computational process, or to try and speed up the workflow by improving the workflow. Since an improved workflow seemed of bigger scientific relevance, the research shifted focus towards developing the next generation workflow.
The last issue involves implementing the final result in practice would be the validation of the performance simulations. The tools found within Grasshopper for assessing visual and thermal comfort; Radiance and Energyplus (via Ladybug and Honeybee) are well suited for architectural design exploration. However, most countries have strict legal requirements on the used methods for validating the climatological performance of a building as part of building standards. Unfortunately, the used PCA methodology would not fit these requirements for many cases. This would cause the need for yet another software to validate the design and obtain the required building permits.

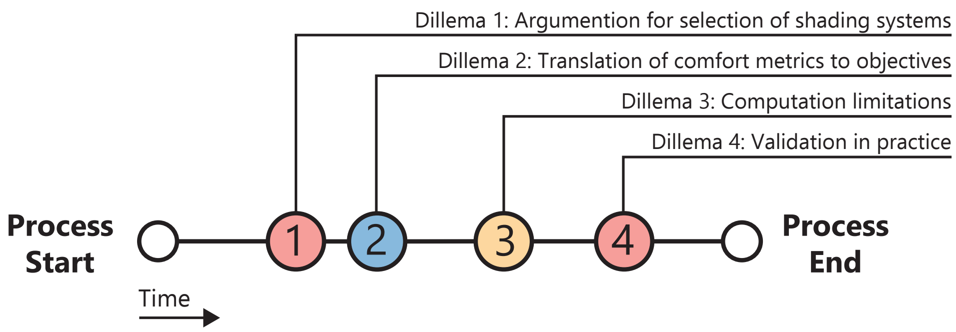

Figure 6. *Diagram: ethical issues & dilemmas (by author)*