A bio-inspired solution for a thermo regulative façade

Graduation plan

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Introduction

The topic of my graduation project is to design a bio-inspired solution for an adaptive façade. Bio-inspired means that the underlying principles of the design are derived from nature. Adaptive refers to the ability to change its properties according to the circumstances.

A façade can be adaptive in many ways, but in my research I will work on the ability to change the amount of heat loss through the façade in order to control the temperature inside the rooms behind the façade.

For the design context I take an office building located in the Netherlands. This is purely theoretical, no exact location has been defined. The reason I chose for an office building is because offices have a high internal heat load. The people working in there, their computers, the lighting and other equipment all produce heat. On the other hand have people in office buildings often less control about their environment than people in residential buildings. It is not always possible to open a window and temperature and ventilation are regulated centrally.

This report contains the problem statement and the research questions of my graduation project. The objective of the research will be explained. My approach and methodology will be explained, as well as the resources I intent to use. The relevance of the research in a larger scientific framework will be explained. This report contends also a time planning for the next coming months.

Problem Statement

Modern building envelopes become more and more insulated and sealed to decrease the energy demand for heating. Indeed, modern office buildings barely need to be heated anymore. A common problem now is the overheating of buildings in the summer (sometimes also in spring and autumn) and the increased cooling demand. Once the heat is inside the building, it is very difficult to get rid of due to the high insulating value of the façade. Simply opening a window is not an appropriate solution for every building, due to draft, too much heat loss at once and noise from the outside.

The next step in reducing the energy demand of a building is to decrease the energy needed for cooling. Increasing the ventilation rate requires bigger ducts and costs more energy. Research presented in my P2 report shows that a thermo regulative façade could reduce the need for cooling or extra ventilation.

Heat management is a problem much dealt with in nature. Organisms need to maintain their body temperature within certain limits. In fact, homeostasis is one of the preconditions for something to be called ‘life’. In this, nature can form an inspiration for the technical design.

To solve the problem of almost permanent overheating of buildings in an energy efficient way, there is a demand for a façade with an adaptable insulation value. As this problem has already been tackled many times in nature, principles from nature may be an inspiration for a design for a thermo regulative facade.

Research questions

Main research question:

*How can a façade regulate the indoor temperature in an office located in the Netherlands, by using the way nature regulates heat loss as an inspiration, to reduce the amount of energy needed for cooling?*

Sub research questions:

* Which principles from nature are suitable for a thermo regulative façade?
* How can these principles be translated into a technical design?
* What is the temperature range people in an office feel comfortable in and how much higher or lower temperatures are allowed?
* To what extend need the thermal coupling of the façade to be changeable in order to prevent overheating during the summer?
* At what frequency should the façade be able to change its insulating qualities?
Objective of research
The goal of this research is to provide a solution for a common problem in office buildings: The overheating of the building due to internal heat load even during the winter period. A secondary aim of the research is to show that we can learn a lot from nature and we can get inspired by solutions presented by nature. These two objectives will come together into a bio-inspired design for a façade which can manage the amount of heat loss of a building. This façade will reduce the energy demand of the building.

Approach and methodology
To come to a final design, several steps in the research and the design have to be taken. The first step is to collect data. This will be done by literature research, analysing reference projects and collecting relevant examples from nature. For this last thing there are several resources available. The websites AskNature.org and the knowledge based design environment DANE are examples of tools which help to find solutions in nature. The second step is to organize and analyse the collected data. The examples from nature will be organized by their underlying physical principal. From all the examples, a few will be used to analyse further. For this the research method developed by Lydia Badarnah Kadri can be of help. This methodology orders the data by selecting several important points. Then the most promising solutions will be used to develop a concept for the design.

For the development of the concept for the façade it is important that the boundary conditions are clear. The focus with the boundary conditions will be on building physical aspects that have to do with indoor temperatures and thermal comfort. The boundary conditions include the temperature range in which the façade has to manage the indoor temperature, how often the façade has to adapt and how quick it has to be able to adapt. These boundary conditions will be determined by Capsol calculations.

When the boundary conditions are set up appropriately, the most promising solutions from nature can be translated into façade concepts. After developing these concepts to a scale 1:20 they can be compared and tested for usability. The concept which works best will then be developed into a final design. Features that will be compared are the range in which they can change their thermal resistance, how quick they can respond to changing circumstances and the amount of energy they use and save. Moreover there are other aspects like construction, water tightness and durability for example that have to be taken into account.

To test these concepts, calculations about how much they can contribute to the indoor thermal climate will be made. These are hand calculations, simulations in Capsol and programming in Matlab/Simulink.

After one concept is chosen, this concept will be improved and worked out further. A few parts of the design may have to be worked out to a smaller scale, like 1:5. If the design is finished, its ability to regulate the temperature can be tested again. Depending on the design, this can again be done by hand calculations, Capsol simulations or programming in Matlab. This is a circular process: designing, testing, improving. This goes on until the design does not need any more improvements.

The workflow is shown in the diagram on page 4.

Literature and general practice preference
The resources which can be valuable for the research and design can be divided in several categories:

- Literature concerning the topic of bio mimicry
- Literature concerning adaptive facades
- Online databases with biological examples
- Modelling programs for determining the performance of the design
Literature about bio mimicry
- L. BADARNAH KADRI 2012. *Towards the living envelope*, Zutphen, Wöhrmann Print Service B.V.

Literature about adaptive facades

Online databases
- www.asknature.org
- http://dilab.cc.gatech.edu/dane/

Modelling programs
- Capsol, Matlab/Simulink
- Autocad
- Maya, Rhinoceros

![Diagram](image)

Figure 1: Workflow
Reflection: relevance of research

The effect of global warming is already noticeable on earth. By burning fossil fuels, we keep adding CO₂ in the atmosphere, increasing this effect. Besides the greenhouse effect, we face depletion of our natural resources. In the U.S. for example, buildings are responsible for approximately 40% of the energy use, and about 13% of the energy use is used for cooling. As buildings become increasingly well insulated, cooling becomes more important than heating. There are already buildings which do not need heating at all, due to optimal orientation and insulation. The downside of these well insulated buildings is that heat, once inside, is not easily discharged.

A façade with an adaptive insulation could solve this problem. This way, the energy used for cooling can be reduced. This reduces the need for fossil fuels and the emission of greenhouse gasses.

As stated before, the problem of how to maintain a constant indoor temperature while the outside temperature fluctuates, is something already solved in nature. There is a lot of knowledge that can be found in nature, but it is barely used in the building environment at the moment.

Time Planning

The research period can be divided in 3 periods: the first period is from the P1 to the P2, the second period from P2 to P3 and the third period is from P3 to P4. After the P4, time is spent to finalise the report and the drawings.

In the first period the focus will be on collecting information. Literature research, analyses of reference projects and collecting and analysing examples from nature will be the focus of this period. The boundary conditions will be determined. The first period ends with a report that contains all the research done so far and the first concepts.

The third period is about developing the concepts, the choice for one concept and creating the final design. The concepts are tested and compared with each other. One will be worked out into a final design. After the P4, there is a little time left to make a few changes or create the last pictures. At P5 the graduation project is finished.

The diagram below shows the schedule for the graduation. The table shows the planning per week. The last diagram shows the workflow.

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1 http://howcanihelpsandiego.com/lighter-side-of-green/