Reflection:

Design and Computational Modelling for a Shape Memory Alloy-based Adaptronic Architecture

P5 reflection for Master Thesis
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Reflection

Relationship between research and design

The main question of the thesis was:

In terms of structure and detailing, how can an adaptronic atrium be designed to self-actuate in response to external environmental conditions, for the purposes of energy consumption reduction, in temperate climate regions?

A literature study was done on Shape Memory Alloys, a type of smart material which is able to change shape if the temperature changes. A deeper mathematical study into the thermal and mechanical behaviours of the material was done and from the findings, the most suitable model for uniaxial behaviour was chosen. A user-friendly software tool was made that allows a user to input the properties and shape of an SMA element along with a description of its antagonistic structure, and see how it behaves when the temperature is changed. This tool gave a convenient method of design for a material that could be complex to understand and would normally require specialist understanding in order design with. The model became instantly useful for realising the implications of using and exploiting the material in certain ways. With findings from both the literature study and the computational model, a concept design was made and some exploration followed. Physical experiments were done to inspect some nitinol for use as a prototype. The prototype engine was thereafter produced, with the capability of actuating a rotating arm by electric heating, and returning to the rest position when cooled. Activation by solar power was done separately. With the experiment and prototypes carried out, a final design was made which incorporated all the learnings and thereby deliver a design for an adaptronic atrium.

The thesis therefore took a journey which dived into cycles of research and design based on what needed to be found out next in order to answer the main question and push the performance of the adaptronics further. To summarise, the journey went through material science literature, reference project literature, computational tool scripting and exploration, concept design, and physical experiments in order to conceive a final design.

Relevance for the Sustainability Studio and Society

An agent against the highly intensive energy costs of HVAC

The thesis fits into the Sustainability Studio, the only studio of the Building Technology Track, as it seeks to tackle a major contributor of carbon emissions and thereby also find societal relevance. Governments and international bodies are increasingly applying pressure on buildings and all other human activities to cut down on energy and fossil fuel consumption, in order to stave off the potentially catastrophic consequences of climate change. The situation places great responsibility on the thoughtful design of energetically sustainable facades, as the heating and cooling of spaces consume 14% of all energy in the EU. Designing against HVAC consumption would therefore be a very logical strategy, and the concept of a seasonal atrium has the potential to cut down heating load by about a quarter in the case of a home in Amsterdam. It would therefore be an agent against the highly intensive energy costs of HVAC.

Scientific Relevance

Adaptronics: a new method for adaptive facades

Currently, responsive architectural systems for regulating indoor comfort are largely based on electrical sensors, computer controllers and motors. They can be complex to build, as they require a large number of parts, are prone to failure and they take up a lot of space. This thesis explores the possibility of adaptronic technology in the façade, which replaces all the complex electrical hardware with smart materials integrated into a thoughtfully designed structure. Such a device is able to do the job of sensing, computing and reacting simply by harnessing the properties of the smart material as it responds to external stimuli. This has great potential for façade design, as it has the job of separating the stable zone of human comfort on one side from the constantly fluctuating conditions of the outdoors on the other; it achieves its goals most efficiently when it is able to adapt with the current conditions. Adaptronics would be a new method for adaptive façades. In conventional adaptive facades, the adaptiveness is generally achieved with a set of electrical components that animate the façade elements, like a puppet. In adaptronics, the adaptiveness goes one level deeper, into the materials themselves.

Empowering the designer with Shape Memory Technology

Shape Memory Alloys have not yet been widely used in architecture, yet it has great potential for a range of applications besides using it as an actuator. For example, it can be a very effective connector, solid sealant, dampener and structural healing device. The complexity of its behaviour is one of the major barriers to its design, as virtually all past projects required a deep understanding and modelling of its dynamic phenomena. Throughout the thesis, a constant effort was made to remove that barrier and find methods to incorporate SMAs into the design process of a non-specialist as well as adapting the material to the physical capabilities of the construction industry, which tends to favour conservative approaches. The script produced is able to model the material as it changes with temperature, without needing specialist knowledge. The tool will empower designers to incorporate the shape memory technology into their own projects, and for climate engineers, it makes it possible to track the changing opening sizes with changes in weather, and thereby evaluate the resulting energy and comfort parameters of the indoor condition.

Ethical issues and dilemmas

The study on atria did briefly touch upon the attitude that clients may have when constructing them. For some corporations, atria are a feature which can represent the wealth, sophistication and power of the brand, with little or no regard for the energy-consuming implications from such a structure. It is important to remember that any act of construction is one that could leave decades of carbon contrail in the potentially intensive operating footprint. Even for zero-energy buildings, the energy and carbon cost in the act of building can be immense. The findings regarding the dominance of building-related energy consumption was therefore a reminder of the responsibility one must have when creating built fabric. For a project such as the adaptronic atrium, the responsibility manifests in the intention to make the atrium as an energy-positive architectural element instead of a net energy consumer.

Another issue is the nature of distributing free software. Firstly, with regards to properly acknowledging the sources that it has been built upon. The landmark paper of L.C. Brinson (1993), which gave the mathematical model for the software, has been credited within the file itself. Secondly, there was a decision to be made regarding how free it would be. In the end, a Creative Commons Attribution 4.0 International License was chosen, which is the most free option and allows the software to be shared and commercially used.