Simplexity

Panagiotis Michalatos ¹, Sawako Kaijima ²
¹² Adams Kara Taylor, UK
http://www.akt-uk.com/
¹ Panmic@akt-uk.com, ² Sawako@akt-uk.com

Abstract. In this paper we discuss the design process that enables the integration of multiple concerns at an early stage of design by combining them into a single field that preconditions the space within which a specific design solution is developed. Our method is closely related to the development of interactive software tools that help the designer form a new intuition about the problem at hand. Two guiding concepts in this endeavour are simplexity [the desire to fine tune and build a system that yields a solution to a specific design problem by collapsing its inherent complexity] and defamiliarization [a side effect of having to represent things as numbers]. To demonstrate our strategy we will present the development of a computational design solution for small scale objects.

Keywords: Stress tensor, digital design

Introduction

During the past two decades we have witnessed the ever increasing adoption of digital media in the field of architecture. The initial effort in architecture trying to incorporate digital media was, as it is usually the case with new technologies, rather opportunistic in exploring its formal potential. In such a context, complexity became one of the common themes associated to digital design, typically judging from the formal outcome. There lies the misconception that advanced tools give advanced results and the confusion between the logically possible on one side and the technically, technologically and economically possible on the other. While it is true that digital media can open up complex information even beyond our perceptual capabilities, internal or external complexity is not sufficient in framing a direction or a goal.

A lot of the problems with ‘complexity’ in relation to digital design stem from an attempt to use programming in order to construct a pseudo science of design and hence justify and present as rational inherently irrational choices. We would argue that programming cannot be the basis for a design science since programming itself is a craft. This becomes apparent if one considers that a good computer scientist is not necessarily a good programmer, and a good programmer is not necessarily a good designer. The first is about theoretical knowledge and the second is associated with experience and technical artisanship, while the third includes the ability to make aesthetic judgment, ethical considerations and tectonics. Programming is not taught directly but is rather mastered through practice while theoretical principles of programming can be taught. Moreover there is a complementary concept to complexity borrowed by system theory which can help us to
frame the aims, possibilities, aesthetics and ethics of computational design.

**Simplexity**

Simplexity is the complementary term to complexity we are going to employ in order to show a different path that one can follow when using digital media in design. The use of simplistic rule systems with only stylistic visual considerations gives rise to the clichés of complexity. There is however, a whole class of algorithms that deal with simplification instead of proliferation. These are usually more complex and require stronger engagement with the concept lying underneath the computation. Simplification in a way that produces meaningful results and renders the complex system more accessible to human thought or more efficient is harder to achieve. This is because reduction, selection and abstraction are procedures that require intelligent and responsible choices as well as some way to refer and operate on the totality of a system. The emergent simplicity out of such intricate and complex set of rules is called simplexity. Many of these algorithms require from the designer a deeper understanding of the system. Simplexity is the aesthetics of a programming craft that results from thorough fine tuning of the design system and expresses the will to understand and make decisions rather than to proliferate and decorate. The designer as decision maker is important in this process. Hence in our approach to developing customized software we give some consideration to the user interface so that algorithms open up to the designer rather than working as black boxes.

**Defamiliarization**

One aspect of the programming craft is the necessity to choose a numerical base representation of objects. This forces the designer/programmer to select properties or aspects of objects relevant to the problem considered and decide how to best represent them numerically and retroactively to reframe the problem he/she has to solve. This can have profound effects on how one perceives and operates on objects. Karatani in Architecture as metaphor notes that:

"The flaw in Euclid’s work lies in his reliance on perception, or natural language, and in his inference of the straight line and point."

"From the moment Descartes defined points as coordinates of numbers, the point and line segment in geometry became an issue of numbers."

We see here that the use of a numerical representation for points was the decisive move that led to modern differential geometry and the break with intuition. We recognize an affinity between this side effect of choosing a numerical representation and the concept of defamiliarization.

Defamiliarization is a technique widely used in art that was described by Viktor Shklovsky in the beginning of the 20th century. The aim is to achieve a specific effect of slowing down perception and halting the automatic, habitual interpretation of things. Here we are not considering defamiliarization as a technique but as a necessity implicit in having to choose a numerical representation. Being forced to think of an object as a set of quantities means that
one has to momentarily abandon the habitual perception of a problem and the automated solutions one developed through training in an architectural schools.

The following sections present the design method developed that illustrates the concepts discussed thereof.

**Design in a Tensor Field**

Our method consists in choosing a minimal representation for a design problem and defamiliarizing with it by raising it temporarily to a more complex mathematical object such as a tensor field with all design concerns superimposed. Subsequently we interrogate the constructed field and extract the information we need to carry the design.

More specifically, here we will present our method developed in order to design light shades that express their structural behaviour. To do so we chose to develop interactive software tools that allow the designer to interrogate and make informed choices within the stress tensor field of a bound volume of material in space. At this level the numerical representation of the field is not accessible any more to the designer’s intuition and one has to defamiliarize with what ‘hanging an object’ or a ‘hanging object’ is. Interactive software tools are developed thereafter in order to extract information from this field and help the designer engage and develop a new intuition and a more tactile relationship with the underlying field and set of concerns.

**The 3d stress tensor field**

From a structural point of view the design of the light shade was a problem of suspension. An idea about how to describe the desired structural configuration...
of a project without attaching any particular form to it came from topology optimization methods where a volume of variable density material is assumed in space and the problem is set up as a set of support conditions and forces acting on this volume. After running this model through Finite element analysis one gets the stress tensor field within this volume. The stress tensor represents the way forces are acting locally perpendicular and parallel to planes in all spatial directions. For most engineering applications one would look in a quadratic composition of the elements of the stress tensor called the von Mises stress a scalar that approximately expresses how hard the material is working locally.

Another influence we had came from work done on the topology of tensor fields. In this respect scalar quantities such as von Mises stress are less important than the eigenvectors of the stress tensor, which yield the principal stress directions. Along these directions there are no shear stresses but only stresses normal to their corresponding planes. It makes it easier to ‘read’ complex behaviour within the material because along these directions one gets pure compression or tension and the integral curves of these eigenvectors give lines that roughly flow from support points to applied loads in a rather more intuitive way. In effect the principal stress directions give a differential coordinate system at each point in space within the material volume.

In the beginning our work focused on different ways to interactively visualize the information packed in the stress tensor so that we can develop a more tactile relationship to it in order to design. In addition the introduction of a differential field within our design space makes the space itself non homogeneous and anisotropic. Design becomes a process of reading and interpreting a field.

Software the interactivity of interrogation

In order to be able to make use of the information in the tensor field we had to develop interactive software that would allow us to visualize and extract or manipulate geometric objects from the field.

We built our software as a post analysis program which has to interface with external structural analysis package. In our case the analysis software was sofistik. The developed software allows the user to interactively place support conditions and loads and save settings and configurations in xml files. It will transparently call sofistik and generate the appropriate files for the structural analysis as well as read back the results automatically. From the recovered stress tensors the software can extract principal stress directions and produce bundles of stress lines in different ways. Because there is no way to visualize the totality of the stress tensor field one can only understand aspects of it, like scalar properties or eigenvectors. Because one can interrogate what happens to the field around a point and not as a whole one has to develop a tactile rather than visual relationship to the field understanding how its behaviour changes from one location to the next and what happens along different geometric loci [normal sections etc...]. The user will gradually develop a mental image of the field itself.

The software allows the extraction of stress

Figure 3
User interface
The prototypes

For the first prototype we used two anti-symmetric supports at the top of the volume that correspond to the incoming supporting wires and four symmetric loads at the base of the volume representing the light bulb and the light shade hanging.

The resulting tensor field suggested two loops or bundles in tension that support the light and light shade independently. Twisting compression rings and 8 shapes form around these bundles.

One of the compression twisting shapes was extracted to form a compression and shaping element.

The light shade was rendered as a surface with a slight twist normal to one of the principal stresses. The manufacturing technique chosen was SLS and these materials are rather brittle and not very well behaved in tension. Therefore, we only kept the...
topology of the two tension loops and rendered them as a wire weaving between the two suspended elements.

The light bulb is suspended above the light shade by the same wire loop. In the end we get a relatively complex configuration of three distinct elements in balance. The light shade itself is a laminate of two perforated surfaces and a network of linear elements in between whose density reflects the field’s intensity at these points.

The objective was to make decisions guided by a preconditioning of design space [in this case by the

Figure 5
prototype light shade.
stress tensor field] where consistency is more important than optimization.

**Further development**

The use of tensor fields to precondition design space allows us to merge multiple concerns within a single description as well as treat space as a continuum of variable densities. Even if the final result is composed of disjoint objects they do share a common logic and mutual formal interdependence. Our next project consists in designing pairs or sets of different objects as if they were one. The case will be made by a light and a table combined field. In addition the move from surface to volume is aided by the promise of new fabrication technologies that allow the small scale manipulation of material. Traditionally the laying out of reinforcement in concrete was made in a way that it was roughly aligned to the principal direction of tension in a slab. Modern techniques allow for a more fine tuned control of what is happening within the material volume and the creation of new composites where reinforcement is visible and closely aligned to the structural behavior of the object similar to the way the grain of wood hints at the anisotropy and specificity of the material to the tree’s support requirements.

**References**
