The Search for Intensional Form

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Louis Kahn, the famous architect, when wandering in his mythical land of Zero and contemplating the beginning of the colonnade that was first expressed architecturally in ancient Greece, described the moment of the creation of the colonnade like this: the walls parted and the colonnade came into being. Like Jacques Derrida discovering the spaces between words, Louis Kahn was able to see what can be called an *intensional* moment, uncovering the architectural essence that resulted in the creation of the colonnade. Or was it really an 'intentional' moment?

According to the Encyclopedia Britannica (2008), in Logic, there is a distinction between *intension* and *extension.* These two are correlative words that indicate the reference of a term or concept: *intension indicates the internal content of a term or concept that constitutes its formal definition; and extension indicates its range of applicability by naming the particular objects that it denotes. For instance, the intension of 'ship' as a substantive is 'vehicle for conveyance on water,' whereas its extension embraces such things as cargo ships, passenger ships, battleships, and sailing ships. The distinction between intension and extension is not the same as that between connotation and denotation.*

The *intensional* aspect above opens up a number of possibilities for the generation of forms. As a simple prelude to thinking about *intensional* form as an inherent, essential form, and how it could be applied, we should question how we would use water as a context and conveyance as a functional need, and then come up with the *extensional* forms of various kinds of ships. How would the hull be shaped to create a buoyant form? How would the bow be shaped? The basic form of a ship could be parametrically determined, incorporating the weight of the ship's material, the volume it encloses (and thereby the water it displaces), and the load it is supposed to carry. This parametric definition could very well be the *intensional* aspect that can be used to generate the *extensional* form of the ship. Maybe the parametric definition of a form is its *intensional* aspect that is used to derive all *extensional* referents of the form. Or is the generation of the ship's form external to the whole process of defining what a ship is?

In Architecture, the *intensional* definition of a beam is a horizontal device used to transfer forces horizontally to a set of supports that transfer the vertical forces to the ground. The essence of the beam is a closely compacted set of moments of forces that act to set up opposing lines of compression and tension and result in the horizontal transfer of a vertical force. How does one come up with the form of a beam, when contemplating the transfer of a vertical force horizontally? Maybe the generation of the *intensional* form of the beam, or the essential form of a beam could be the result of a set of rules or of an algorithmic process. How would that process be structured? It could be scripted using a programming language; in other words, it could be represented using a formal system. The great leaps in Architecture have been its *intensional* moments, such as when the walls parted and the colonnade came into being, or when the beam came into being to span across a space.

How does a form synthesizer such as **form•Z** facilitate the creation of *intensional* forms? The basic set of geometric primitives available in **form•Z** enables one to synthesize myriad forms by combining the primitives using Boolean operations. This enables the creation of a variety of *extensional* forms. How is an *intensional* aspect integrated in this synthesis? It is probably not, but exists as a separate process in the mind of the designer. For example, an *intensional* aspect of a 'triangle' is that 'the sum of its internal angles is equal to two

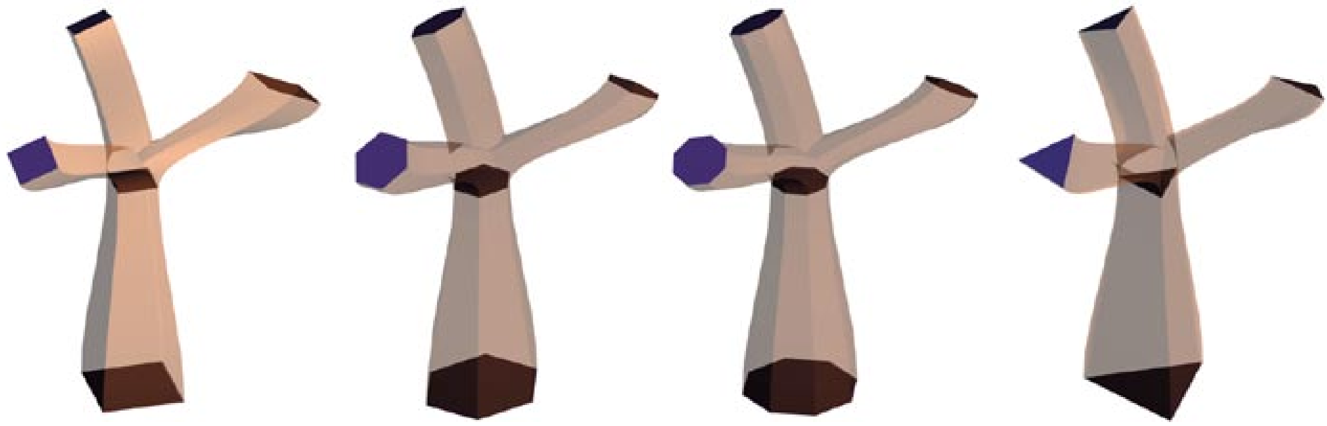

Figure 1: The creation of extensional form from intensional aspects using form.Z.

right angles.' The challenge is to specify this aspect as a form generator to create a triangle. Do current scripting languages allow this kind of specification? In short, how can one go from an *intensional* aspect or definition to many *extensional* forms?

Maybe **form•Z** should become a form finder, instead of a form synthesizer or simple rendering engine. In the traditional usage of modeling tools, the *intensional* aspect of a form that has been synthesized is ascribed typically after the creation of the form, without the *intensional* aspect being instrumental in the creation of the form. A new frontier to explore is how these *intensional* aspects can be incorporated into the dialogue of software tools thereby enabling such *intensional* definitions to be used in the creation of *extensional* forms. The answers to these questions will define the search for *intensional* forms.

There is hope. The answer may be in tools such as Sweep, Revolve, and Loft that begin to enable the generation of forms from an *intensional* aspect. Shown above is a figure that indicates how *intensional* aspects such as cross-sections can lead to the generation of a structural element (in this case a branched column), based on implied lines of force and specific section moduli distributed in space, using the S-Loft tool in **form•Z**.

In Figure 1, an *intensional* aspect, a section modulus, is used to generate a number of *extensional* solutions that differ in form. The various cross sections, at the various spatial locations used to generate the *extensional* forms, all correlate to the same sectional modulus in each spatial location, describe the same *intensional* aspect.

The architect Aldo van Eyck once described a house as "the constructed counterform of homecoming." In the traditional architectural design process, "homecoming" with all its connotations (not *intensions* or *extensions*), helps generate the form of the house. Maybe there is a path of form generation (or "counterform" generation as Aldo van Eyck would have it) from "homecoming" to a "house" that is *intensional,* or, it proceeds from essential properties to the *extensional* form. Is this kind of path computable? Can this kind of form generation be expressed as an algorithm? I have argued that it can be (i).

An insight occurred to me when I was looking at some isocandle diagrams in Gyorgy Doczi's book, the *Power of Limits* (1981). In the image of Figure 2, I have juxtaposed the photo of a moth with the isocandle diagrams from Doczi's book. Is it not fairly typical for a moth to be attracted to lamps that emit light that follows an isocandle distribution that is similar in form to itself? Often the heat of the lamp kills or burns the moth, yet it seeks the proverbial 'flame' of the lamp. Does the moth sense that it is akin to the light distribution form of the lamp? Does it 'resonate' (which is an acoustical word applied to light here) with the *intensional* form implied by the lamp? Could an *intensional* aspect be a hidden stimulus that generates a response, a response as basic as a perception of the essence of the form? How would this be different from an analytical diagram imposed on the form from the outside?

Upon further meditation on the juxtaposition of isocandle diagrams and moths, we can see that the isocandle diagrams are actually sections of a three-dimensional isocandle field. The wing structures of the moths are planar. The affinities are in the boundary shapes. Can we generate the form of the moth from transformations of the isocandle diagram? What tools would we use in **form•Z** to do this? Could we use the Revolve tool to generate the body of the moth? Could we use the tool to generate a surface from a boundary to create the wings of the moth? All these are plausible. What is the *intensional* or essential form of the moth? How is this form expressed? Is it using a graph or a diagram? We would have to choose between using a graph (ii) or a contour diagram, depending on our *intensional* or *extensional* stance. A discovery that would result from our choice is the *intensional* or essential form of the moth.

In Logic, *intensional* statements and their truth-value are critical. *Intensional* statements are used to get at the essence of a class of entities. If an entity embodied the *intensional* aspect of a class of entities, it would most definitely belong to that class. What if an *intensional* aspect of a class of forms was a performance criterion? Then all the *extensional* referents that have this *intensional* aspect embodied could be expected to perform as desired. We could then generate forms of performance (iii) from the *intensional* aspects.

We could consider **form•Z** as a formal system that allows it to be used for propositional calculus. We could map the 3D forms that we create using **form•Z** as formulas created within a formal system with atomic entities (geometric primitives) and logical operators (Boolean operators). Well-formed formulas (wff) in this formal system would be 3D forms created without errors. The challenge would be to determine the truth-value of these well-formed 3D forms. The distinction between the well-formed 3D forms, and the ones with errors, would then be the distinction between the fantastic and the constructible. In a sense, if you generate a form using **form•Z** without errors, it should be constructible, say using a 3D printer.

Forms that are defined algorithmically using artificial programming languages may be inherently *extensional* in nature. This is because the artificial languages used to generate them are *extensional*. It all depends on how transparent the artificial programming language is in the form generation tools in **form•Z**, such that the form generation moves from an *extensional* realm to an *intensional* realm. In the example of the branched structural element, an abstract distribution of different section moduli in space, each of which is determined by an impinging force, is used to generate a form that satisfies the structural properties implied by the directionally-oriented section moduli. In this example, a set of performance conditions (*intensional* aspects) is spatially distributed to generate a structural form. This is a very powerful process for form generation that may give rise to a method for creating with the *intensional* aspect in Architecture.

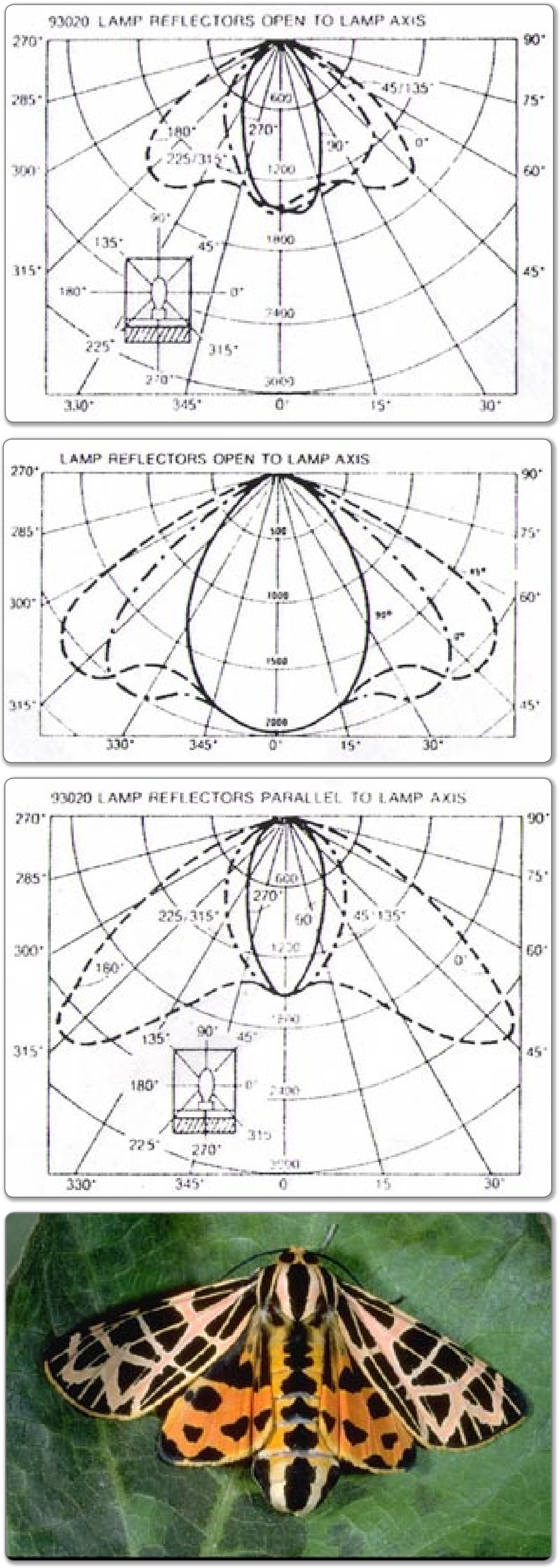

Figure 2: Formal congruency of a moth and an isocandle diagram.

Let us project this scenario, by envisioning a computer-based software tool that generates forms based on *intensional* definitions. Consider a software tool that helps a designer generate candidate forms for bridges. The tool could allow the definition of lines of force that the bridge must support, and the loads implied along the lines of force. Whether these forces are in compression or tension could be specified, or they should be determined from the network of forces acting to define the bridge structure. This can be accomplished by a simple graphic editing tool and an algorithm that analyzes graphs. Based on a building material suggested by the designer, the software tool could first suggest the cross-sectional areas required to carry the implied loads, and follow it up with sectional moduli orthogonal to the lines of force. With the *intensional* definitions of the cross-sectional area and the section modulus, the software could generate candidate shapes that satisfy the performance requirements that are implied by the cross-sectional area and the section modulus. The shapes could be generated using the well-established methods of a shape grammar with applied constraints. With the shapes decided, then a tool such as the S-Loft tool in **form•Z** could be used to generate the structural form of the bridge based on the *intensional* definitions and the performance criteria implied by the *intensional* definitions. By changing the lines of force, or the implied loads, or the building materials of the bridge, the form of the bridge can be transformed. This can be made to happen in near real-time for powerful design feedback. This would make the software tool a vehicle for exploring design alternatives in the early stage of the design process. Such tools need not work at the macro scale only, such as with bridges. We could consider a similar tool to articulate the structure of artificial bone replacement parts, using hundreds of lines of force with complex section moduli and constraints. The custom bone replacement parts could then be digitally fabricated.

The software tool described is just a single example. This class of software tools would be all about form-finding: a form-finding based on satisfying multiple performance criteria. The next generation of CAD tools should focus on form-finding based on performance, which would be a vast improvement over a synthesize-test-transform-test, or iterative set of production tools. Since form-finding is an essential aspect of the architectural design process, occurring at all levels and scales of the design process, there exists a plethora of opportunities to create such tools for various form-finding tasks in Architecture.

Notes

i The process of generation of the spatial enclosure of a proscenium-type auditorium from acoustical, programmatic and functional parameters, was successfully implemented as an algorithmic process in the Algorithmic Auditorium project completed by Mahalingam (Mahalingam, 1998).
ii The representation of architectural design using an uniform connections-based paradigm, based on graphs was explicated in a paper presented by Mahalingam at the ACADIA 2003 conference (Mahalingam, 2003).
iii The generation of forms of performance from performance criteria were explored in a digital design studio at North Dakota State University by Mahalingam (Mahalingam, 2005).

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