Algorithmic Transparency

Sergio Araya
Massachusetts Institute of Technology
School of Architecture, PhD in Design and Computation
Massachusetts Avenue 77 room 9.268
sergio_a@mit.edu

Abstract
This paper describes the procedures developed in the creation of an innovative technique to design and manufacture composite materials with transparency and translucency properties. The long term objective of this research is to develop a method to design and fabricate architectural elements. The immediate objective is to develop the methodology and procedural techniques to design and manufacture a composite material with controlled non homogeneous transparency properties. A secondary objective is to explore different levels of "embedded behavior" or responsiveness by using these techniques to combine different physical material properties on new designed "smarter" and "responsive" composite materials.

1 Introduction

> *"Transparency may be an inherent quality of substance, as in a glass curtain wall; or it may be an inherent quality of organization. One can, for this reason, distinguish between a literal and a phenomenal transparency."*[1]

One very evident consequence of the adoption of modern technologies in the contemporary city is the result of the separation of structure and skin which is manifest in the proliferation of transparent building envelopes. For some critics this has also implied the vanishing of the façade, or of '*architecture's face*' as pointed out by Anthony Vidler.[2] Several years before, Colin Rowe had established a distinction between literal and phenomenal transparency by comparing façade treatments on Le Corbusier and Gropius buildings. By doing so he left open questions about the use and interpretation of transparency in architecture, as a material physical condition and/or as a spatial or organizational condition. While this paper is not trying to respond or contest any of Rowe's interpretations, it tries to build from these distinctions; it presents an operational and instrumental approach within a framework initiated from these distinctions.

This paper elaborates on the possibility of applying a design procedural approach to develop non homogeneous material properties, transparency and translucency. Fixed definitions of such properties, where for example transparency and opaqueness are interpreted as absolute values and pure states, are challenged by actual creating gradual variation, and continuous yet heterogeneous performative values. Furthermore, it explains how a different condition, specifically related to material transparency, is developed which could be categorized as an ambiguous or intermediate stage between the literal and the phenomenal stages defined by Rowe: a *multifarius transparency*, where these stages can be copresent simultaneously. The method developed here consists in using procedural composition techniques combining different materials with different material attributes to create new properties. Optical fibers were chosen to take advantage of their conductive qualities.

Optical fibers conduce light from one end to the other based on absolute internal reflection. This gives the composite another characteristic, different from that of glass or other transparent materials: depth, or freedom of location. And it embeds in the component the possibility of spatial depth or spatial transparency, beyond surface depth into volumetric and spatial depth. I will call this *deep transparency*.

> *"The figures are endowed with transparency; that is they are able to interpenetrate without an optical destruction of each other. Transparency however implies more than an optical characteristic, it implies a broader spatial order. Transparency means a simultaneous perception of different spatial locations. Space not only recedes but fluctuates in a continuous activity. The position of the transparent figures has equivocal meaning as one sees each figure now as the closer now as the further one"*[3]

A second question raised by Rowe is that coming from his formalistic analysis, where formal organization beyond material conditions, played an essential role in identifying these characteristics. In that regard, this paper presents the layered logics embedded in the creation, development and fabrication of these elements in a number of prototypes of different degrees of development and with different levels of functionality. This organizational relation creates a second characteristic: divergence, or freedom of coherence. I will call this *distributed transparency*.

In *Figure 1* a testing prototype incorporating optical fibers of varying sizes and grid ratios illustrates the effect of material composition in the performative attributes achieved.

Figure 1. Material composition and performance

2 Methods: Deep transparency, distributed transparency

The research described in this paper, was conceived as a sequential series of explorations which combine design routines and CNC fabrication techniques. Custom procedures were developed for these experiments, and learning from each implementation, adjustments and therefore variations within these procedures, were pursued in order to exploit observed properties in the resulting prototypes. The application of this research is used later in further implementations to create three-dimensional display systems. This further development required also investigation on image and signal processing in order to match the right bits of information with the distributed array of pixels produced through the method described in this paper. That specific research, developed by designer Orkan Telhan, will not be included in this presentation, and is subject to its own publication. Detailed here is the research related to the design and fabrication of the physical implementation of such system. Part of the investigation and of the prototyping was done in collaboration with designer Hector Ouilhet, especially those aspects of the research related to the adaptation of these principles to the later implementation as a threedimensional display system.

The method presented here, decomposes a particular media input into a myriad of small bits, transports each of them through space ant then reassembles them, gaining in the process two degrees of freedom, location, which enable deep transparency, and coherence, which enable distributed transparency. Location because this method allows having transparency translated from its origin to a new, possibly distant location. Fibers can be bundled, piped and embedded within a substrate, transporting information/data from one point to a distant other. Coherence because it has to be reorganized to reproduce the information/data, and this can be done in infinite ways. It can be reassembled consistently with the original input, but it can also be fragmented and distributed, can be reorganized to encrypt the original input or simply decomposed to a myriad of bits and scattered thorough space. This enabled the physical routing of the fibers to act as a material computing device, enabling the creation of "image editing filters". As shown in *Figure 2* a process of splitting in a number of bits and then routing them through a distance, takes place. Later a reassembly of such bits or pixels is required to reconstitute the source.

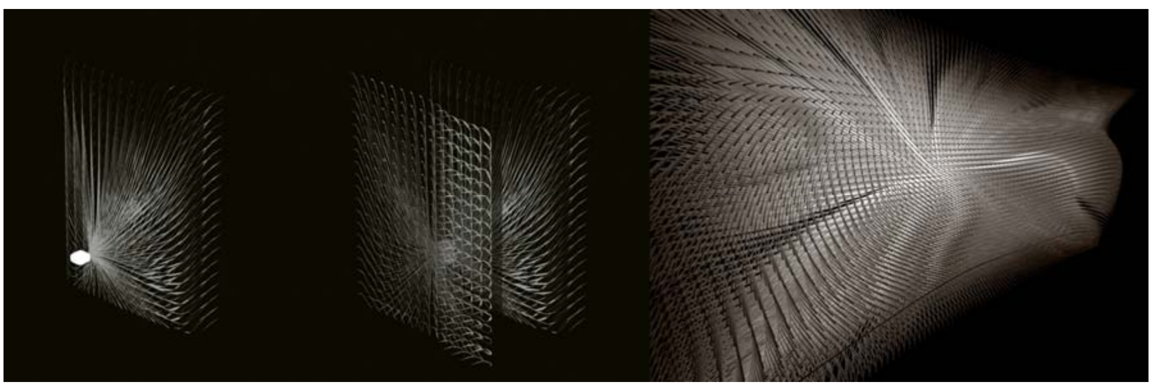

Figure 2. Organizational spatial transparency, beyond mere physical.

The starting point for a matrix distribution is a regular orthogonal grid. A grid is an optimal distribution of the fibers on the matrix material, from a logistical as from a data management perspective, but a non homogenous and organic distribution was a design driver of this research. Specifically targeting the gradual distribution of material properties in the final composite. Gradients, scattering, patterning and other compositions are made available as performative variations

Several layers of transformation were overlaid in order to produce an ambiguous yet defined condition of organization. As in liquid crystals, a nematic phase is seek and achieved, a condition that is *in-the-process-of-becoming-but-not-yet*, between order and disorder, between fluid and rigid. Both aesthetics and function are affected by this reorganization. *Figures 3 and 4.* Shows a composition where both depth (location) and distribution (coherence) are variable and non homogeneous.

Figure 3. Continuous gradients of material distribution

Figure 4. Spatial organizational transparency, beyond mere physical.

Current developments, including some new products in the available in the market today, have used fiber optics embedded in building materials, such as concrete. Most of these designs though, exploit the properties of the material only from their physical transparency, ignoring the capacities present on the composite material through their organizational transparency, that which add two new degrees of freedom, location (depth) and coherence (order). Furthermore, all this attempts are basically recreating those properties present in glass, so these concrete tiles behave similarly to translucent glass. These explorations intend to expand the range of effects embodied in these components, to enhance the modes in which they affect architectural space.

3 Material Composition

Composites materials are generally made by the combination of two basic materials, a matrix and reinforcement. The matrix surrounds the reinforcement and fixes it in place, while the reinforcement contributes the mechanical and physical properties that enhance the matrix properties. This method proposes the creation of a non homogenous composite material. The material is formed by the distribution of a transparent reinforcement (fiber optics) within a non transparent matrix. The distribution is done using a custom develop program that operates on a parametric model, where density, variation and location are variable parameters.

Given the conductivity of the optical fibers, light would travel through in both directions. A system where this potential could be used to display a video source is created, where each fiber is homologued to a pixel of the video source. *Figure 5.* Shows a test where a video source is fed to the input end of the fibers, acting as a distributed pixel system. *Figure 6.* Demonstrates the bidirectionality of the conductivity, when a prototype is place outdoors, and while being fed a video source from one end, on the other end a person passes by and the silhouettes are translucent to the video input side, only using the sunlight as light source.

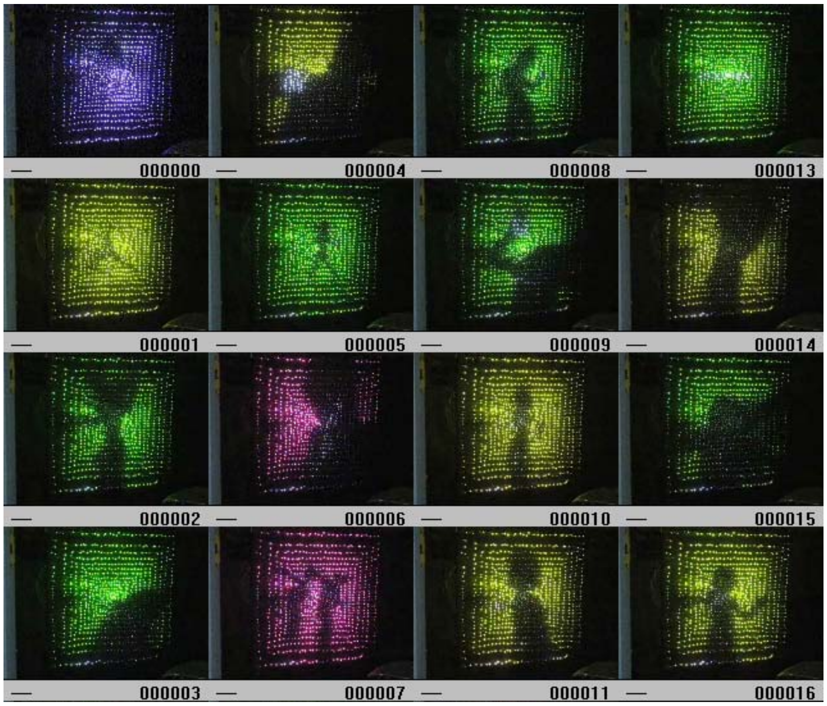

Figure 5. Distributed transparency for pixel liberation

To operate such match a series of transformations are required and are described below. The procedure implemented consists of a series of scripted functions that manage the different stages of the material design. The project implements five stages of development:

- **On-surface distribution** (this procedure takes a digitally modeled object and uses an algorithmic distribution to create a pattern on the surface of the object using local variables and adjustable parameters)
- **Unfolded distribution** (this procedure takes an approximated facetted and unfolded set of shapes and unfolds the distribution pattern based on local positions)
- **Optimized distribution** (this procedure reorganizes the distribution pattern using a transformation of the original relative positions to an absolute position on a rectangular grid of tag-numbered shapes)
- **Matrix distribution** (this procedure creates a list of every point or fiber location so it can be read by the parser application which would later be responsible to assign the correct pixel to each fiber, each fiber location is still relative inside the local surface, in order to relate to the actual distribution, but ordered in a uniform grid in order to relate to the input distribution)
- **Uniform input distribution** (this procedure takes the total number of fibers in the matrix and optimizes their location in order to create a consistent and uniform grid, for the input side)

Figure 6.Dual sided display performance

Although theoretically, only two distributions are needed, input and output, practically, when the prototypes were scaled up in size and number, some intermediate steps were required. Specifically targeting the later implementation as a display, the complexity of the assembly process and the prefiguration of possible maintenance issues, demanded a series of “control screens” in order to properly track and organize the fibers in smaller groups, and also to aid in error correction process after assembled. This set of solutions is required both to locate and control each fiber position individually but also for checkups and maintenance purposes, in case a replacement is needed.

3.1 On Surface Distribution

The fiber distribution over the object’s surface was written as a scripted routine inside a parametric platform, Generative Components. The objective was to facilitate the early design phases, iteration and decision making by controlling certain variables which would determine the distribution. The routine requires a digital model to apply the distribution on, to which it is independent of, precisely to be able to explore different design alternatives. The object’s surface is then subdivided to be able to address local areas with adhoc precision. This subdivision is control by a set of values that provide both linear and non linear sets of values, resulting in a non uniform subdivision system that enhances the ability to target specifically conflicting areas (such as extremely convoluted double curved moments of the surface).
The density of points to be created inside each surface subdivision is controlled by independent variables for its relative U and V values. This implementation used a uniform set of values for each surface subdivision as it was easier to manage later on the backend side to individually assign each pixel to a specific fiber.

3.2 Unfolded Distribution

Several test were perfomed using CNC techniques, but given the complex form factor of the later prototypes, a 5 or maybe even 7 axis CNC router would be required to align the spindle normal to the surface at every point and drill accordingly. Given the limitations in time and budget, some prototypes used approximated surfaces and all-parallel milling, some in a 3 axis CNC router. The more complex prototype used a different procedure. An alternative path is delineated and decided to have a printed set of patterns which could be used to cover the surface of the object and use it as a template to drill all the holes to pass and fix each fiber. The procedure then takes the information of the surface subdivision obtained in the previous stage and projects a new approximated surface using flat triangular facets. This projection is needed in order to unfold the surface of the object which is a complex double curved surface, therefore not developable. Each facet is then translated to another plane and aligned and rotated in order to unfold the facetted model in continuous strips using the V direction as guidance. The local relative position of each fiber is read from the ON-SURFACE distribution pattern and then reapplied to locate every point on the new set of unfolded surface subdivisions. Finally each unfolded strip is tag-numbered in order to facilitate the assembly process later.

3.3 Optimized Distribution

The process by which a light source is going to be focused and directed to one end of the fibers in order to channel the light through them requires a packed set of fibers on one end and a distribution of all the tips on the other end, according to certain rules. In order to track and identify each fiber in the system (individualize each pixel) it is imperative to build a registry that targets both distribution patterns (both ends). For this purpose a distribution set holds each group of fibers, as they are located in each surface patch, it creates an isolated and unfolded version of each patch, tags each of them so each fiber position can then be localized and isolated, for checking or maintenance of the installation. There are two panels, each of them belong to one half of the object, which for management as well as fabrication purposes, was designed as two complementary halves that lock together with magnetic locks.

3.4 Matrix Distribution

This transformation takes each fiber position on the object and records its relative jnew uniformed and normalized version of each of the patches. The gaps and spaces are still present as in the original pattern, but the aspect ratio of the patches is now uniform and can be homologated to the media aspect ratio. This new distribution has all panels organized in a continuous grid, where all patches are contiguous, as now they are all of the same dimensions. By this method the fibers are packed together, although still maintaining its position. This new relative positions are recorded and use to manufacture a control panel where the fibers are assembled and packed. It is also recorded by the program by exporting a text file with the location of each fiber on each isolated patch. These locations are based on UV values which are then read by a parser that interprets these positions in order to send the appropriate bit of information, or pixel in the Cloud project case, to the corresponding fiber.

3.5 Uniform Input Distribution

This final transformation is required as the media input from the projector needs a continuous medium to project onto or some bits of light would be lost between the gaps. This function basically packs together all the fibers, eliminating the spaces in between, creating an homogeneous bundle of packaged fibers. For this distribution, each fiber exists in a 2 dimensional array, as they belong to the patch based on UV values. They are then rearranged in a one dimensional list (linear) where ach fiber is consequently listed and concatenated with the next fiber from the next path, leaving a "gap" value to indicate the end and beginning of a new patch. The transformation is recorded and passed to the software parser as it needs to locate each fiber in the new arrangement to mask and send the proper bit or pixel. *Figure 7.* Show these transformations.

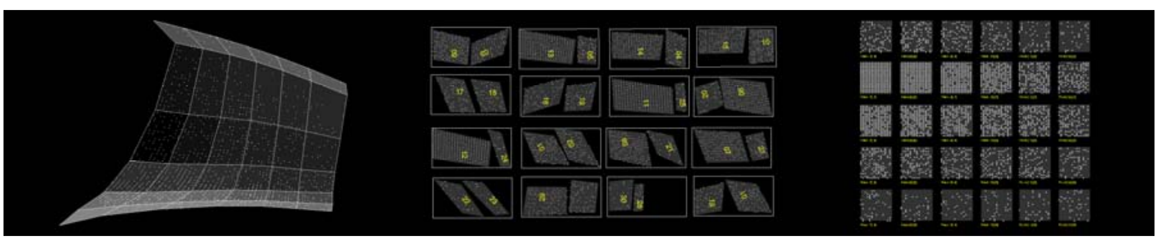

Figure 7. Matrix transformations

4 Discussion and (in)Conclusions

The work presented here is an ongoing research project and therefore no definitive conclusions are made, but open discussions relating the design procedures, the material results and the theoretical implications of such practices are opened and offered.

4.1 Hylomorphism and material culture

Widespread among architects and designers, the concept of materiality has become a wildcard to refer to various conditions, characteristics and attributes of materials and their multiple uses. In general it refers vaguely and ambiguously to such conditions and attributes, it implies from a consideration in the use and choice of materials in design, to a careful and studied theoretical position regarding materials in a practice that deals both with virtual (abstract) representations and with actual (concrete) objects as products of such practice. Some critics argue that this makes the emphasis on merely superficial, sometimes even obvious if not shallow, notions of a perceptual interpretation of materials. It evokes a "heightened sensibility toward the use of materials within an architectural context (...) the applied material qualities of a thing"[4]. As Fernandez remarks, this notion is usually used to described evident and explicit properties of materials, and usually circumscribe the description and discussion of such material properties to only "the haptic and visual aspects of materials" neglecting other aspects related to its performance properties. He asks for a deep, specific, and concrete attitude towards materials, from physical, chemical and mechanical properties to performative and qualitative attributes should be carefully considered while choosing and using a specific material.

Raoul Bunschoten on the contrary, describes the interest of his practice in the dynamics of materiality, present in different scales, "from the thinking hand molding a ball of clay" to the" process of human activities, exchanges and emotions at the urban scale". Bunschoten refers to this as the "skin of the earth as a dynamic materiality, and the inhabited space: the second skin"[5]. He sees these processes as the place where "architectural artifacts (small worlds)" happen. He sees concrete material processes through a conceptual framework of meta-processes that understand the urban and the natural as their place of action, their field of interaction.

Architects and designers traditionally have understood materials as the substance with which they work to create and shape their ideas. Katie Lloyd points precisely to this relation, between matter and form in the design process, where material (or matter) "is inert - as that which is given form"[6] through design, materials are shaped or formed. Historically the architects role has been regarded within the discipline as "form giver", a definition which relies on the separation of both *form* and *matter*, as "form is that which can differentiate and form which can be differentiated"[7]. Katie Lloyd calls this differentiation *Hylomorphism*, and places this dichothomic relationship between matter and form within a historical and philosophical context, where the abstract representation has always had a predominant role in the practice of architecture. Lloyd Thomas points to an emergent attitude, not yet radical enough to question these assumptions, but strong and spread enough to start shifting the balance in contemporary architectural discourse about its material practice, she call this new attitude "material attention". While this material attention still accepts the hylomorphism paradigm, they try to reestablish some balance to the equation, at least to "replace neglect" with this new attentiveness. She concludes her essay by asking (if not expecting) a more radical reinterpretation and implementation of this framework, especially when after the soft (ware) digital revolution we are experimenting the hard (ware) digital revolution, and when new technologies such as CNC manufacturing, are "recentering the discussion as a link between conceptualization and production, undoing a gap which has been such an important part of the discipline's structuring"[8]

The massification of new technologies and the emergence of whole new paradigms in relation to material manipulation and making, are slowly transforming the ways in which form is though in relation to the matter it would shape. In the adoption of digital technologies, from the "personal computer to the personal fabricator"[9] we are stepping into the field of *Digital Craft*, where both conceptualization and materialization take place virtually and actually.

To speculate about the implications of these emergent techniques within the practice, this paper presented some explorations on developing techniques within a design process to be implemented using CNC technologies. This exploration's aim is to investigate possible avenues for further research, when applying design methodologies to specifically develop and exploit material attributes and qualities. *Figure 8.* Illustrate the different stages at which computational design contributed to rethink and explore material distribution to enable material performativity.

Figure 8. Performative materiality through material distribution

4.2 Transparency distribution (pushing glass)

Engaged in an investigation that wanted to depart from exploiting material configurations, rather than formal designs results through materials, the initial explorations were freed from a global design objective and remained at a local physical level. Form in those cases was a resource used to pursue and develop material properties. Shapes and patterns then become vehicles of addressing gradual distribution of material conditions, rather than formalistic results.

By 1996, William J. Mitchell talked about the future of the city as a networked machine, he used the term "*Pulling Glass*"[10] to refer to the act of wiring physical places, building the Infobahn. Today we all live in such space, and the spaces, places and infobahn as prefigured by him, are facts. The transformations of such places, and human behavior accordingly, have been studied extensively.

I will borrow such term to refer to a new possibility, "*Pushing Glass*". Pushing beyond standard conceptions of finite and absolute conditions, of standardized and uniformed attributes and qualities, all derived from the modern paradigm of mass production and standardization. Pushing also material distribution to enable performative functions beyond the standard inherent physical properties of matter, possibilitating deep transparencies, and distributed spatial transparencies.

4.3 Algorithmic Transparency

This conception of matter as continuous gradual allocation of performative functionalities instead of simple aggregation of discrete elements with diverse qualities, allows a new understanding our material practice. Traditional divergent values can now be seen as converging forces in continuous fields of variation, the relation between interior and exterior, between built object and landscape, can be reinterpreted, can at least be challenged. This presents an opportunity for altering and radically challenging our physical environment now, the same that has been transformed virtually during the last decades, now by affecting its actual physicality, concretely, transforming passive material into active matter. Specifically in relation

to the explorations entailed in this paper, by extending standard notions of material properties, such as transparency, to that of algorithmic transparency.
To explore transparency distribution different procedures were scripted thus several different patterns were produced. Manipulation of the distribution allows creating distortion or altering effects to the light/image source. Through these ordering procedures, a sort of analog filter for image manipulation can be created, relying on the physical conductive properties of the fibers and their translation in space from their input to their output. The study of distribution patterns isolates every variable parameter involved in the final distribution algorithm:

- Relative position (plane location in relation to the original grid)
- Relative depth (in relation to the plane)
- Relative distance (in relation to their neighbors)
- Continuity (homogeneous distribution versus scattered distribution)
- Size (variation in fiber diameter)

These algorithms should be refined and further research will be conducted in order to explore other potential behaviors derived from the manipulation of these and other parameters

4.4 Material Computing (machine matters)

A machine, as derived from the latin root *machina*, means a "an assemblage of parts that transmit forces, motion, and energy one to another in a predetermined manner"[1], hence by pushing beyond the physical transparency properties of glass towards a distributed multifarious transparency, we could think that this artifacts behave as computing machines.
Starting with the different patterns studied several potentials in terms of material properties and possible embedded behaviors appear. A potential for extending these transparency properties through larger spatial conditions, exploring light conducting both for sustainable lightning purposes as well as for performative displaying reasons. Relocating transparency from one space to the other. Rethinking transparency through its potential organization (design): encrypted transparency, displaced transparency, scattered transparency, distributed transparency.

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6 Endnotes and References

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