Material Cognition: Designer's Perception of Material in a Creative Design Process

Shani Sharif
Georgia Institute of Technology, USA
shani@gatech.edu

Abstract

The new trends in digital design and fabrication attempt to utilize material information as a generative factor in the design and form exploration processes. An investigation on the designers' cognitive processes in perceiving materiality in an integrated design process could potentially impact these integrated digital endeavors. As a result, this research explores the role of materiality as an external representation based on two main concepts in cognitive science, situated and distributed cognition.

Keywords: Material; Material integrated design; Distributed cognition; Representation.

Introduction

The current trend in digital design and fabrication is mostly dependent on a hierarchical relationship between form generation and physical material, which became the dominant trend in computer-aided design (CAD) in the last decades. In these practices, the notion of *materiality* and material information is a passive property assigned to geometrically defined objects, rather than being a generative factor in the design process as it was established in the traditional systems of design. On the other hand, knowledge about materials, e.g. wood, clay or stone, is inherent in traditional systems of design such as craftsmanship and architecture in which form creation is nourished by designers' notions and experiences of different material qualities and their associated techniques of fabrication. Traditional design systems take a holistic approach to design where form creation, its visualization and finally physical embodiment are coincident in the designers' creation process. New forms emerge while designers experiment and transform raw materials, or sketch based on their perceptions gained through previous creations. In the same fashion, in the last few years, with the ever-increasing application of digital fabrication machinery, new attempts mainly in the scale of design-built projects have been made, aligned to traditional design process, to replace the passive notion of materiality, and use material information as a generative factor in the design process. In these projects and studies, the goal has been to encode and integrate the material information and fabrication/machining data as generative and parametric factors in form exploration (Gramazio, Kohler, & Oesterle, 2010; Menges, 2012; Oxman, 2012; Schroepfer & Margolis, 2006).

As a result, this study focuses on the designers' cognition of material qualities in traditional design processes: in a (creative) design process, how designers (sculpture, or architect) perceive (different) materials in order to transform it into a design object (with use of different methods and tools)? In this light, this research proposes a conceptual framework that focuses on the different aspects of designers' cognition of material qualities in design processes; or, in a creative design process, how designers perceive materials in order to transform it into a design object. Understanding and properly using materials in a design process could be studied through the concepts of: *situated cognition,* with which design cognition can be analyzed in practice as the relation between a designer and a social or physical situation (Greeno, 1989); and *distributed cognition*, as design idea and material understanding are developed and taken form in action, in a culturally structured setting (Hutchins, 2000; Lave, 1988). In other words, material and its deformation would be the context of physical emergence for design ideas, where knowledge representation and design communication in a social group play critical roles.

A Situated Cognition Approach: Materiality In The Process Of Design

The art and work of design in different scales from sculpture and painting to architecture can be translated as the engagement of the designer with the context through the medium of the design or *material*. This material context for a sculptor can be glass, clay or metal, and for an architect it would be concrete, brick or steel. The engagement of the designer with the material of design can be studies through a situated cognition approach. MIT Encyclopedia of Cognitive Science defines situated cognition as "the study of cognition within its natural context. […] Situated cognition emphasizes on the physical, environmental, and social contexts for cognition" (Wilson & Keil, 1999). The situated cognition approach asserts that the nature of cognitive processes become meaningful in the interaction of mind and environment, and it just can be studied within a distributed system in which it is embedded.

Situated cognition studies assert that the ability of the problem solving not only depends on the acquired knowledge of the individual, but also on the individual ability to *transfer* that knowledge to the situation they are in (Greeno, 1989). Specifically

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in the design process, novice designers in order to generate a buildable design solution should be able to transfer the knowledge they have gained through lectures and instructions on material properties and structures to be applied in the materialized context of design. Here, *context* is defined as “physical or task-based (including artifacts and external representations of information), environment or ecological (such as workplace), and social or interactional (as in educational instruction)” (Wilson & Keil, 1999). Coming up with the design solution depends on the individual’s ability to retrieve the relevant piece of knowledge she has previously acquired for performing in a specific environment. As a result, this knowledge must incorporate the detailed understanding of the structural features of the environment.

Internalizing the Practical Knowledge through Practice

The practical *knowledge*, necessary for the design process and the materialization of design artifact, is developed as the embodied relation with environment through *practice*. Keller and Keller refer to knowledge as “not a static collection of information, but rather the disparate and dynamic conceptual entities that individuals use in their various activities”. Here the *practice* is defined as “the observable behavior performed in the production of an artifact, the sequence of operations in which individuals engage” (C. M. Keller & J. D. Keller, 1996). In producing a design artifact, knowledge and practice are in tandem, and they form a complex interdependence (C. Keller & J. D. Keller, 1996). In other words, knowledge is the abstraction form of experience, which integrates the social, cultural and environmental phenomena. In fact, the knowledge that is internalized through practice later is externalized through different representation media in the design process.

In the relation between knowledge and practice, O’Connor describes the process of achieving proficient practical knowledge through her experience in glassblowing (O’Connor, 2007). The glassblowing, like other works of art, is comprised of a set of skills, as components in a process. The novice observes each step demonstrated by the expert, instructed on each step as they are explained, and practices each component skill separately “like successive point on a line”. However the proficiency in the process is not achieved in mere linking of these consecutive actions. She compares the skill set of the novice with those of the experts and argues that proficient practical knowledge is gained through an insight which sees the component parts of a making process not as ends to themselves, but rather the role they serve as a *whole*. In this process the skills sets withdraw from consciousness and become extensions of the body, a shift away from “an awareness of particularities towards the whole” (O’Connor, 2007).

Externalizing the Practical Knowledge through Representation

The embodied practical knowledge of the designer, which was gained through experience, transforms into externalized representations in a design process. The first aspect in understanding of role of materials in the design process is to distinguish it as a medium of design *representation*. In the process of transformation of a design idea to a design artifact, the designer converts the *internal image* in their mind to sketches or scaled models to consequently come up with the best possible solution as the final design. Internal image is a concept that is defined in *mental models* framework. In this framework, mental model is a thought experiment – a structural, behavioral, or functional analog representation of a real-world or imaginary situation, event, or process. Mental models are used in different cognitive tasks, including reasoning, problem solving, and comprehension. These representations could be imagistic or perceptual in format (Nersessian, 2008).

The transformation of a design idea to a design artifact requires that the designers clarify the design ideas in their minds by the production and modification of different representations through the interaction of these representations with the environment (Eugene S Ferguson, 1992). In the design of artifacts, Ferguson argues that when a designer thinks about many features and qualities of the design object, most of them cannot be reduced to unambiguous verbal descriptions, but rather they are explored in their minds by a visual, non-verbal process (Eugene S Ferguson, 1977). Material is one of the media in the interaction between internal and external representations in the designer’s cognitive achievements in the design process (Brereton, 2004). The design process can be described as the “propagation of representational states across a variety of media.” The situated cognition provides the opportunity to use a unified language to cover cognitive processes inside and outside the heads of designers. The knowledge of design is learned and transformed in the mind of designer as an internal representation and through communication with others it will become externalized and shared to shape the complete cognitive process, as Herbert Simons asserted: “solving a problem simply means representing it so as to make the solution transparent” (Simon, 1996).

There are different types of representations brought into play by designers in every design processes. Although the application weight of representations varies based on the type of design, for example in artist-maker design process, or architect, they can be categorized in specific dimensions. Brereton classifies designers’ representations in four categories: internal vs. external, transient vs. durable, self-generated vs. ready-made, and finally abstract vs. concrete (Brereton, 2004).

Design Representation

Internal vs. External

Internal representations are in the designers mind and there is no direct access to it. When these thoughts transform into words, drawings, or built models they become external representations, which can be shared with other members of the social group.

Transient vs. Durable

Transient representations are externalized by designers in form of words or body gestures, but they cannot be captured and preserved. While, durable representations are those such as sketches and physical prototypes that are persistent and can be kept for future references.

Self-generated vs. Ready-made

Self-generated representations are directly produced by designers such as words, sketches, or physical models. On the other hand, designers may take advantage of existing products in their environment, such as images or pieces of other models, for developing their ideas or communicating them with others.

Abstract vs. Concrete

Representations are abstraction of the final design objects in different degrees. For example early design stage conceptual sketches have higher degree of abstraction to those drawings in the final stages of the design process. The same concept applied to the physical models, a scaled model is an abstraction of the final design object represents just some of the aspects of the final design, while a full-scale model resembling a part or the whole design is closer to a concrete representation. As Brereton mentions "abstract representations offer more flexibility in interpretations than concrete ones. And different representations convey different kinds of information more directly than others." As a result, appropriateness of the representations is determined by the type of information they would convey in different design stages (Brereton, 2004).

Distributed Cognition Approach: Design Materialization as a Collaborative Process in a Social Context

The organization of the cognitive system consists of different range of mechanisms. These mechanisms from a distributed cognition point view, as Hutchins defines, are the coordination between the *internal* and *external* structures in a cognitive system (Hutchins, 2000). In this definition, external structure is the social setting for an activity.

Cognitive activity in a social context is distributed among the members of a group, and consequently, cognitive properties of a team have to be studies as a whole and based on the interaction among the members (Hutchins, 1995). In this definition, the important property of social groups as an aggregate system is that "they may give rise to forms of organization that cannot develop in the component parts" (Hutchins, 2000). It can be inferred that the knowledge that is produced in such a context is also fundamentally social in origin, and a designer's knowledge and information shapes within the social milieu of people, artifacts, etc. based on the communication of the designer with the social environment (Brereton, 2004). Communication in a social group is the key to access the accumulated knowledge of a group. If the individual memory is considered as the communication with self over time, the substitution of this intrapersonal communication with interpersonal communication with other team members would result in the transition from an individual task to a team performed task (Hutchins, 1995).

In addition, the communication in a design process provides the context for learning. The designer's cumulative design knowledge grows and is transformed through practice that are understood and evaluated in the context derived from the ideas and products of others through different types of transient and durable representations. In this framework, the design formation is an outcome of social interaction, as well as personal experience gained through practice (C. M. Keller & J. D. Keller, 1996).

It can be concluded that based on this definition, the influence of culture on cognitive accomplishments is indispensible to the extent that they must be identified as the joint accomplishments, not attributable to any individual (Hutchins, 1996). Any cognitive activity, including the process of design and design materialization, constantly evolves in different developmental aspects. First, in these activities, designers utilize techniques and tools that are developed as the result of hundreds of years of design and technological innovations. Second, every designer has a pool of knowledge and practical skills. This expertise has been gained through years of practice. Third, the development aspect, as Hutchins defines it, is the "micro-genesis" of the designer cognition in social interactive with the milieu, as most of the artifact design and fabrication activity is performed as a joint process in a group with different knowledge and level of expertise. Finally, in the development of each activity, the cognition micro-genesis of the designer shapes the culture for those who follow, in the same manner, as they were dependent on the innovations of those who preceded them (Hutchins, 1996).

Material Representation and Social Context, in Artisan's and Architect's Way of Design

Every design process is consisted of a series of cycled representations in abstract and material form (re-representation), which helps to clarify and sharpen the internal design idea (Brereton, 2004). In this process materials are considered as reconfigurable concrete external representations, which based on the scale and requirements of the design subject, i.e. work of art or architecture may come into play in different stages of the process. Ferguson highlights this design processes based on different objectives of the design artifact as: the artisan's way (designing without drawings), and the engineer's [architect's] way (designing with drawings) (Eugene S Ferguson, 1992). In artisan way of design, the internal design representation in the artisan mind is directly transformed on suitable materials. In this process, although there might be some form of preliminary sketches involved, the main requirements are only materials, tools and skill for transformation of material to the design artifact. In other words, there is no distinction between designer and maker. In the artisan way, there are fewer representation types involved in the process and the transition between internal and external is more immediate. The transient external representations are transformed to durable representations in material form. In the work of artisan there is no gap in the transition between material as an abstract representation and the material as a concrete representation, or the final artifact. In addition, the scale of the material external representation remains mostly the same, close to the scale of the final design product.

On the other hand, in the architect's way of design, the designer (internal) and maker (external) are not the same persons, and design is not a direct process as in the artisan's way. In this way, design is a collaborative process in a social context, where the designer has to represent the design ideas communicable to the makers of the design. Although Ferguson asserts that "the conversation of an idea to an artifact, which engages both the designer and the maker will always be far closer to art than to science", the dissociation between the participants requires the engagement of a greater number of representation types in the process. Both transient and durable abstract external representations such as conversations and drawings have necessary roles in the design development. However, it should be taken into account that the important point for a successful design is that the process should be interactive rather than linear. The flow of information should not be just from the designer to the maker, but it has to be a two-way dialogue with input and feedback between both designer and maker. The tacit knowledge and the skill that workers gain through practice in working with materials and material transformation has to be integrated as essential components in the design process.

"The training of Filippo Brunelleschi, Francesco di Giorgio, and Leonardo da Vinci included apprenticeships in which they learned how to prepare and use he materials required to make drawings, paint pictures, and produce sculptures in stone and metal. Their knowledge was based on sensual observation, and they were guided by masters who showed the apprentices what to look for. They were trained as artisans, which today means 'persons skilled in an applied art'" (Eugene S Ferguson, 1992).

Consequently, this interaction is necessary as there are not many designers who are expert in the fabrication process and not only can avoid the unwanted surprises in the design outcome as a result of the ignorance of the designer of the nature of materials and manual skills, but also are able to embed the craft knowledge as an importation deriving factor in the design development.

Conclusion

The role of material as an external representation in a design process has been studied through the concepts of situated and distributed cognition. The practical knowledge of material behavior and transformation, which is gained by practice, has a critical effect on design process in the work of both artisan and architect, although it may come into play in different design stages for these two groups of designers. In addition, the material knowledge and its representation have to become a bidirectional communication medium between designers and makers in a social design team for a more effective design process.

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