

The representation of post design(*v.*) design(*n.*) information

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Abstract. Attempts to address interoperability issues in digital design information have become stilted. A lack of any real success is more indicative of the questions asked rather than the solutions proposed. If design information is the progenitor of design representation, and representation is a method by which to encode, store, and distribute design information, then the issues associated with digital design information can be seen as special cases of the general the problems associated with communication. Considering a representation by asking: ‘What is the information that needs to be communicated?’ and, ‘With whom is this information being communicated?’ may provide a better perspective from which to assess specific technological problems such as software interoperability. The goal of this paper is a call to attention – an exercise in critical thought and a provocation. Can re-conceptualizing the problems with the representation and interoperability of digital design information as generic problems of communication offer insight on novel solutions? A brief overview of the challenges posed to interoperability is presented along with current and past efforts to address this issue. An alternative methodology for the communication of design information via process rather than state descriptions is proposed, followed by a summary conclusion.

“In each period of our history, design and communication have evolved synchronously with the technology of the time. Each new medium has extended our sense of reality and each has looked to its predecessor for language and conventions, referencing and adapting its characteristics until its unique capabilities can be explored and codified.”

– Muriel Cooper, 1989.

In order to engage in a critical, digital discourse we must understand, or at least agree upon, a context in which the discourse is to take place. Material matter(s) embody context-independent characteristics and a preferred state of existence based on their physical properties; conversely, digital matter(s) are completely context-dependent and have no “natural” or desired state. Any digital discourse must therefore be framed with respect to the particular problem needing solved. A ‘problem’ in this domain is the discrepancy, or gap, between the desired state of a system and its existing state. In regard to design problems, design tools are the mechanisms by which to bridge this gap through the manifestation of design information. The determination of a design tool’s appropriateness or usefulness can be considered with respect to the facility with which it allows designers to achieve their design goals.

I believe it is helpful to begin with an examination of the ‘deliverables’ of a design process, the design documentation. Effectively all contemporary architectural design documentation attempts to capture design information in the form of a *state description*¹. As such, design documents (including digital / physical drawings, models, visualizations, bills of materials, etc.) are considered the representation of a set of physical and spatial relationships which comprise the design intent. All design documents, material or digital, aim to communicate design information through a process of encoding, storing, and distributing a set of commonly agreed upon signs and symbols - what may be referred to as the architectural vocabulary. If communication is the main driver of documentation, then the effectiveness and fidelity of the communicative effort can be judged by the consistency and conformity of design information across a set of design documents, and between the documents and the built work. Communication theory defines information as “...a measure of one’s freedom of choice when one selects a message.” [1] Information in a design document is therefore a measure of the relative ambiguity present in a given document. In an industry heavily reliant on a communicative enterprise as overwhelmingly ambiguous as the visual² the difficulty of disambiguating design information through annotated,

¹ According to Simon, state descriptions “...characterize the world as sensed; they provide the criteria for identifying objects, often by modeling the objects themselves.” [2]

² The field and study of shape grammars and visual calculating is rooted in the fundamental ambiguity of the multiple ways in which we can see, interpret, and work with the visual world. For more on this topic see *Shape: Talking about Seeing and Doing* Stiny, George (2006). MIT Press: Cambridge, MA.

graphical, state-descriptions becomes exceedingly clear. In short, everyone reads the drawings differently³.

It is important to make the distinction between the *act of design* and the *result of design*. To design - as a verb, as the act of creating, planning, or calculating in service of a predetermined end⁴ - certain associative leaps and intuitive design decisions are presumed which should not be unduly constrained in advance. However, a design – as a noun, as the expected result of a particular process can, should, and must be analytically rationalized into a series of discrete procedures from which it can be derived. This of course presupposes a direct link between a design process and the processes by which the design is materialized. In a profession increasingly reliant on the use of digital design tools for the automated generation and rationalization of form, the contractual separation⁵ of a design goal from the means and methods by which it is to be realized retards the entire Architectural, Engineering, and Construction (AEC) industry. It is no longer productive for design descriptions to be contractually isolated from its process of fabrication and assembly. As Dennis Shelden noted in *Tectonics, Economics and the Reconfiguration of Practice: The Case for Process Change by Digital Means*, our "Capabilities for the geometric expressions of form - enabled by advances in digital media - have moved beyond the capacities of 'conventional' project descriptions to effectively capture and process project intentions into building...A key aspect of this catalytic force is *the potential for directly repurposing information* through various stages of project definition and execution." (emphasis added) [3]. It is the potential to directly repurpose information that characterizes the greatest opportunities for design via digital media, "extending our sense of reality" and providing insight on how to free digital technology from the "language and conventions" of its material predecessors [4].

"First, the taking in of scattered particulars under one Idea, so that everyone understands what is being talked about..."

- Plato, Phaedrus, 265D

By moving away from material-dependent design manifestations Computer Aided Design (CAD) established a means for capturing, storing, and processing the information necessary to re-present a design object as explicit relationships between abstract-symbolic entities. This critical difference was noted by its creator, Ivan Sutherland, in 1975⁶. Twenty years later, this distinction was

³ For more on the problematic nature of communication see "The Conduit Metaphor" by Michael Reddy in *Metaphor and Thought*, Ortony, A. (ed.) (1993). Cambridge University Press: England. 2nd Edition.

⁴ Paraphrased from Merriam-Websters Unabridged Online definition 1.g..

⁵ According to the American Institute of Architects document B101-2007 *Standard Form of Agreement Between Architect and Owner*, section 3.6.1.2. the designer is barred from explicitly specifying the means and methods by which their projects are to be built. Regardless of how integrally the process may be bound to the product, the discretion is left to the builder to choose their preferred methods so long as the final outcome reasonably matches the design documents.

⁶ "To a large extent it has turned out that the usefulness of computer drawings is precisely their structured nature and that this structured nature is precisely the difficulty in making them. I

restated more abstractly; "An analog medium transfers shape to produce an analogue of one physical arrangement in another, analogous one. But digital media transform physical form into conceptual structure. A shape or color is converted into a number whose symbol is then inscribed on a ledger so that it can subsequently be ascertained by a machine or a person. The material out of which this ledger is constructed is incidental to the information stored, unlike the constitutive material defining an analog medium." [5] Current initiatives aimed at achieving greater performance, tighter construction tolerances, greater formal complexity, increased sustainability, and reduced environmental impact - currently generalized under the title BIM (Building Information Modeling) - will only become a reality when the design ledger becomes truly inconsequential. Currently, the most significant impediment to achieving this goal is found in the 'I' of BIM; the transformational axis which portends the means by which a building can be mapped to model and a model to a building⁷. Rather than wasting time, money, and effort on reformatting existing data to satisfy the requirements of software needs⁸, discrete sets of information should be filtered from an overall set of project data as needed, providing for varying design representations to be created on-the-fly without sacrificing the consistency and conformity of the overall design information.

The degree to which digital information may be repurposed is directly related to the technological independence, or interoperability, of the information, which is typically determined by the data structure which houses the information. The majority of attempts to resolve this problem can be categorized as follows: committee-based, standards-based, market-based, and open-source. Committee-based solutions such as the Initial Graphics Exchange Specification (IGES), and the STandard for the Exchange of Product model data (STEP) have suffered from the retarding effects of bureaucratic decision-making, slowing their ability to keep pace with rapid changes in technology. Attempts to create industry standard data structures by commercial geometry kernel providers have failed due to their equalities in readily available, high-quality products (ACIS, Parasolid, etc.).

believe that the computer-aided design community has been slow to recognize and accept this truth. An ordinary draftsman is unconcerned with the structure of his drawing material. Pen and ink or pencil and paper have no inherent structure. They only make dirty marks on paper. The draftsman is concerned principally with the drawings as a representation of the evolving design. The behavior of a computer-produced drawing, on the other hand, is critically dependent upon the topological and geometric structure built up in the computer memory as a result of drawing operations. The drawing itself has properties quite independent of the properties of the object it is describing." [6]

⁷ This suggests seeing BIM not as a tool (as many producers of architectural software purport), but an organizational strategy for storing, and distributing project data. This consideration proposes a framework through which all representations of a project truly become selective partial-orderings from the overall set of project data.

⁸ An overwhelming majority of the effort expended on the analysis of projects which have already been created in a digital format is devoted to input preparation and geometry re-definition specific to each analysis program. See Bazjanac, V. (2001) "Acquisition of Building Geometry in the Simulation of Energy Performance", *Proceedings of Building Simulation '01*, Seventh International IBPSA Conference. pp 305-311.

Market-based approaches by software vendors in the form of all-in-one CAD/CAM/CAE packages such as CATIA (and now the AutoDesk suite of products) result in prohibitively expensive software and licensing costs, and the need for dedicated experts to operate the software with no guarantee of the software being the best choice for every job. Because no single obvious standard has emerged for digital modeling, affiliate programs through which software developers encourage third-parties to develop additional software functionality via plug-ins and APIs (Application Programming Interfaces) have not been widely effective. One of the most recent and heavily supported forays into this field is the Industry Foundation Class (IFC) system⁹. To a large extent, IFC has been built from the STEP framework; however it could arguably be included within any one of the aforementioned categories, increasing its vulnerability to failure.

The common aspect of all these approaches is the consideration of the state description as the only means by which to communicate design information. Rather than more of the same, a critical re-evaluation of means and methods by which we communicate design information is needed. Fabian Sheurer poses the question nicely in his essay *Getting complexity organized: Using self-organisation in architectural construction*, “What is a reasonable quantity of explicit information for a specific design, and how does one communicate it in a reasonable fashion?” [7]. If we abstract the problem of capturing, storing, and distributing design information as a general problem of communication then we can ask two very fundamental questions: ‘What are we trying to communicate?’ and, ‘With whom are we trying to communicate?’. Stated this way, the pre-conditions of *what* and *with whom* provide the criteria with which we can determine the most effective way to subdivide, or filter, a given set of information and the most appropriate method for describing that information (either as a state description, *process description*¹⁰, or both). For example, the type of information and how it is communicated will differ when transferred from person to person, person to machine, or machine to machine.

“After all, nothing is more fundamental in design than formation and discovery of relationships among parts.”
- Bill Mitchell, 1995.

Contemporary generative design techniques such as ‘scripting’ encode explicit relational rule-sets in high-level computer languages that can, to a certain extent,

⁹ IFC was developed by the International Alliance for Interoperability (IAI), an international consortium of commercial companies and research organizations founded in 1995. The actual development work is carried out by a six member group known as the Model Support Group. Software applications must become “IFC Compliant” in order to import and export IFC files from their native data structure to the IFC-standard data structure. Also, the object-oriented nature of IFC allows third-party users to create new entities not currently defined in the IFC model called “proxies”.

¹⁰ A characterization of “...the world as acted upon; [process descriptions] provide the means for producing or generating the objects having the desired characteristics.” [8]

be read by people as well as compiled by computers in executable machine code. These scripts capture a post-rationalized set of steps (rule-schema) that facilitate the derivation of structured data (visualized by most design software in the form of geometry) from a given set of variables and pre-determined conditions. Because the relationships between the variables and conditionals must be explicitly and logically embedded in the rule-schema, and each derivation of the script is dependent on the values assigned to the independent and dependent variables – its context - these methods are inherently parametric; change a variable, re-run the script, and the entire system will be re-evaluated accordingly. In addition, because such schema can be stated as step-wise procedures from an existing state to a desired state, it can always be stated in a technologically-independent format.

Correlated with increases in the use of scripting are increases in the availability of proprietary design software, many which are packaged with their own individual scripting language. Assuming the trend toward generative techniques will spill over into mainstream practice, the necessity to consider, rationalize, and explicitly capture in schema the processes and relationships by which a design is derived will also increase. Process descriptions may be able to provide a more consistent means for communicating design information in a less ambiguous way. Seen this way, design solutions are not singular entities but discrete instances of a set of evaluated design rules in a particular context. Changes to the context only effect the derivation, not the design itself. A state description can be used in conjunction with the process description to check that the design information was communicated correctly, providing a validation for consistency and conformance. The precedence of design-pattern approaches (from which object-oriented programming owes much of its development) and extensible rule schema¹¹ provide working precedence for the encapsulation and dynamic re-combination of discrete rule-sets.

The implementation of such an approach is non-trivial. Mapping information between proprietary data structures is notoriously difficult, and information loss is typically the rule not the exception. Even some proponents of IFC acknowledge that it is just one of many options, and that it may not be the best framework under all circumstances¹². Another challenge is that certain descriptions of space, such as mathematically function-based description like NURBS, are not supported by all digital design tools and must be transformed into faceted approximations before they can be read into non-NURBS programs. This may suffice for visualization, but can lead to significant errors in fabrication and construction. A promising approach would be a general purpose specification (such as XML) that provides the framework for the encapsulation and extensibility of design rules, meaning that rules could be re-written, re-ordered, and added on-the-fly without requiring the entire schema to be redefined. Theoretically, the procedural

¹¹ Such as shape grammars and XML (eXtensible Markup Language).

¹² See “The IFC Building Model: A Look Under the Hood”, online article; Khemlani, L. AECbytes Feature, March 30, 2004. http://www.aecbytes.com/feature/2004/IFCmodel_pr.html

description of a design could contain domain-specific rules (for such domains as structural, electrical, cost-analysis, etc.) to be invoked only by those parties interested – producing domain-specific design representations and reducing the informational clutter with which any one part of the project team would need be concerned. Specification frameworks also provide for the validation of rule-sets with respect to each other, allowing contradictory rules to quickly be identified and addressed. Coincidental to this approach could be the automated translation between software-specific scripts. A direct translation from one scripting language to another may prove prohibitively difficult based on the degree of differentiation between program-specific data structures. For example, there may not be a useful method for translating a script from a NURBS-enabled surface modeler such as Rhinoceros (RhinoScript) to a non-NURBS, constructive solid geometry based program such as AutoCAD (AutoLISP). Although it must be pointed out that the majority of digital fabrication technology, if not all, already performs such transformations of input geometry in order to derive machine tool paths. Thus, at a certain level we have already accepted such approximations¹³. If design schema were written in a ‘universal’ meta-scripting language, a more direct mapping from these scripts to proprietary languages could be achieved. However, it is uncertain if the industry would support the adoption of yet another layer to the design and documentation process, and further research needs to be done.

Conclusion

During a time when a great deal of the contemporary architectural discourse is devoted to assessing the role of the architect, the capability and use of digital technology in architectural design have acted to further remove - rather than re-center – architects from a direct connection with the artefacts of their toil. Architects continue to adopt tools created for and by other industries based on the desire to produce geometrically complex forms and better manage project information. In addition to expanding the technical boundaries of traditional design tools¹⁴, this adoptive approach has led to an exponential increase in the amount of information generated by the AEC industry. The attention issues relating to communication, such as interoperability, have received relative to the effectiveness of the solutions is indicative of the lack of a critical, digital discourse. The continual proliferation of digital tools employed in the design, fabrication, and construction of architectural projects has exacerbated the interoperability issue of technological interoperability which can restrict or prohibit the ability of digital information to be shared amongst project teams. By exploiting the fundamentally unique characteristics of digital media, architects may be able to reposition themselves not just as process consumers, but as process creators, re-establishing the link between thinking and making. While the solution presented here may at best be a schematic proposal, I feel it is important enough

¹³ This would be another problem well worth further investigation.

¹⁴ See section ‘Expanding Design Boundaries’, pp405-408 in Chapter 15 of *Digital Design Media*, second edition; Mitchell, William J. and McCullough, Malcolm (Wiley & Sons, 1995).

to warrant further consideration. More importantly, the focus of digital discourse both in academia and the profession needs to be re-centered on how we communicate digital design information.

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