Ontology for Computational Design

Computational Methods versus Cultural Processes

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Abstract: *In the ongoing taxonomy and ontology work in and about the computational design domain varying progress has been made. While in the ontology work oriented towards computational use within the domain a human-based approach appears favored, in the ontology work focused on the research domain the focus seems to be on computational approaches. This paper proposes to extend the human-based approach to the construction of an online research domain ontology in order to utilize inter-human collaboration to capture the fundamentally cultural phenomenon of language or vocabulary and its agreed upon meaning. Online availability would allow referencing for tagging of contents, for example for use in keyword lists, or for computational categorization of collections. Such an effort would add a research community forum for continued discourse about the research domain.*

Keywords: *Ontology; research domain; semantic web.*

Idea

In the domain of computational design there is ongoing work at the conceptual and the content level on establishing an ontology for various discipline domains proper with the goal of supporting computational approaches to design knowledge elucidation and knowledge exchanges (Lin and Chiu, 2008; Lee et al., 2008; buildingSMART 2007). An ontology for the research domain is still lacking, although various approaches have been discussed (Turk et al., 2001; Bhatt and Kishore, 2008). Considering the prospects of the next iteration of web technology, commonly called Web 3.0 and perhaps, as Silva et al. (2008) point out, in a limited vision labeled "semantic web," this paper proposes a research-community based discursive approach towards development of a research domain ontology for computational design.

Cautionary note

The term "computational design" is as ill-defined as most other terms in this research domain. With increasing definition this term *could* turn out to be synonymous with "computer aided design" (CAD), or *could* be discovered to be a subcategory of CAD. Hypothetically, "computational design" could also be revealed as the supercategory to "computer aided architectural design" (CAAD). Therefore, it is used in this paper as a place holder without any more specific meaning than can be derived from common understanding of its constituent terms, "computational" and "design."

"**com•pu•ta•tion** […] **1** the act of computing; calculation **2** a method of computing […] – **com'pu'tation|al *adj.*"** and "**de•sign** […] ***vt.*** […] **1** to make preliminary sketches of; sketch a pattern or outline for; plan **2** to plan and carry out, esp. by artistic arrangement or in a skillful way […] ***vi.*** […] **2** to make original plans, sketches, patterns, etc.; work as a designer […]." (Neufeld 1988, p. 287 and p. 373, respectively).

Motivation

Spurred by a discussion on the ACADIA e-mail list about the big questions in our field that are unresolved, Wassim Jabi wrote a statement paper about the five areas that he deems most important (Jabi, 2007). One of the five areas, Taxonomy, resonated quite strongly because of the apparent confusion in meta-discussions about the discipline domain. Clearly, meta-discussions are seeds to research and, therefore, good sources of insight into the starting development of a language about the domain, or any deficiencies in that area. The apparent lack of an explicit, consensus-based vocabulary impacts the quality of discourse. At the same time, the process of collaborative construction of a domain terminology may serve as basis for an ongoing discourse about this domain and the research related to it.

Considerations

Taxonomy and ontology

Extending beyond a brief reference to structural definitions in science (Turk et al., 2001) it is initially not obvious whether a taxonomic approach is needed as implied by Jabi's observation, or whether an ontological or any other approach would be more helpful, or what the relationships between these various approaches may be. An attempt of clarification of any differences between these approaches, for example taxonomic versus ontological, may shed light on this issue.

Per Webster's New World Dictionary *taxonomy* is defined as "the science of classification" (Neufeldt 1988, p. 1372), while *ontology* is defined as "the branch of metaphysics dealing with the nature of being, reality, or ultimate substance: cf. PHENOMENOLOGY" or "particular theory about being or reality" (Neufeldt, 1988, p. 947).

Traditional taxonomy is familiar from biological classification, which attempts to explain clades based on a tree of life roughly indicative of the sequential evolutionary inheritance leading to the currently observed speciation. As such, traditional, hierarchical taxonomy is based on the assumption that subsequent levels in the structure have a subdivision relationship to preceding levels, while taxa on the same level have an exclusionary relationship, i.e. an either-or relationship. With newer insights, first as attempts to explain the existence of mitochondria, then as attempts to explain existence of molecular similarities across different branches of the tree through horizontal gene transfer, the rigorous clarity of the branching system has been diluted (Doolittle, 1999 in Figure 1).

In contrast, ontology attempts to describe entities in the world as they are. Horrocks (2008) observes: "Ontology, in its original philosophical sense, is a branch of metaphysics focusing on the study of existence; its objective is to study the structure of the world by determining what entities and types of entities exist." Classification into types of entities, i.e. taxonomy, therefore, is a sub-discipline of ontology. Given the goal of understanding the computational design research domain, constructing a taxonomy does not suffice. In addition, a structure more flexible than a hierarchical tree structure appears necessary. Horrocks continues: "In computer science, an ontology is an engineering artifact, usually a model of (some aspect of) the world; it introduces vocabulary describing various aspects of the domain being

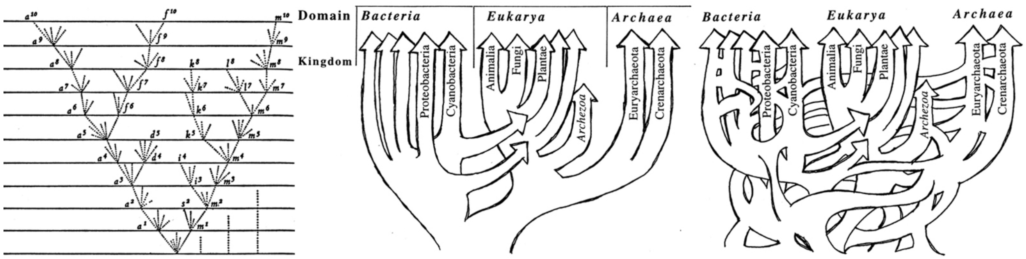

Figure 1
Changing views of biological "tree of life" (Doolittle 1999):(left) Darwin's conceptual sketch, (center) 1999 current consensus, (right) 1999 proposed new view with horizontal gene transfer resulting in a reticulated tree or a network

modeled and provides an explicit specification of the intended meaning of that vocabulary. However, the specification often includes classification-based information […]." (Horrocks, 2008). An additional discussion of ontology can be found in Lee et al. (2008).

An effort of a nature similar to establishment of a research ontology for computational design found an iconic expression in the domain of design theory in Charles Jencks' diachronic plot of architectural styles mapped against a cognitive categorization (unselfconscious to logical). The styles then serve as attractors in the placement of architects showing how they may have changed their approach over time, or have followed different approaches

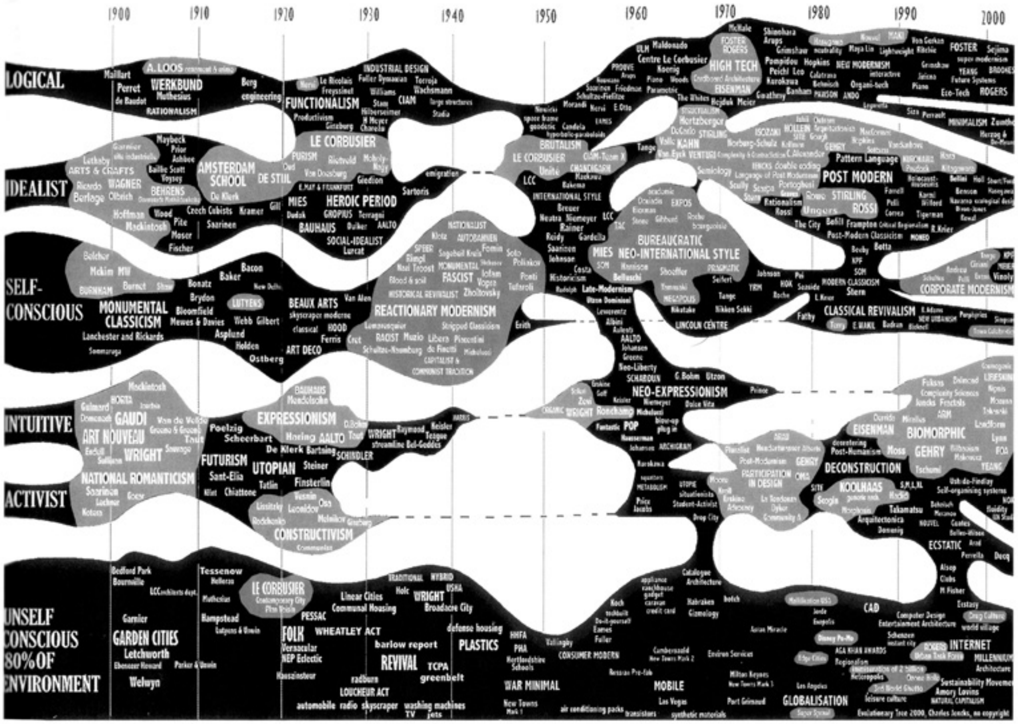

Figure 2
Charles Jencks's iconic map of architectural styles and architects as visualization of relationships between diachronic development and one axis of categorization (unselfconscious to logical) (Routio, 2007; Hill 2008)

286.	**Project management automation**
286.01.	Computer graphics
286.01.01.	Computer-aided design (CAD)
286.01.01.01.	Computer-aided architectural design
286.01.01.02.	Computer-aided engineering
286.01.02.	Architectural animation
286.02.	Computer-aided specifying
286.03.	Building information modeling (BIM)

Figure 3
BIM in the AIA taxonomy (AIA, 2007b, p. 31f.)

almost synchronously (Figure 2). The most obvious problem of this approach is that architects appear in multiple locations on the map, depending on the stylistic categorization of their work at that point in time. Another set of problems is the subjectivity of determining stylistic labels, as well as the labeling of the architects' works.

Ontology as process

"**proc•ess** […] **4** a particular method of doing something, generally involving a number of steps or operations […]." (Neufeld 1988, p. 1072).

BIM is a relatively recent acronym in the domain of computational design. There are various academic and professional publications that describe BIM. Sometimes they contain different expansions of the term, and even when using the same expansion they may have different definitions (BIM Handbook). Users of BIM in practice as well as software vendors have described their definitions, too (BIM Wiki). The Association of General Contractors (AGC) BIM guide equates Building Information Modeling (BIM) with Virtual Design and Construction (VDC) and defines: "***Building Information Modeling*** *is the development and use of the computer software model to simulate the construction and operation of a facility. The resulting model, a* ***Building Information Model****, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility.*" (AGC, 2006)

The American Institute of Architects (AIA) describes BIM: "Building Information Modeling (BIM), a digital, three-dimensional model linked to a database of project information, is one of the most powerful tools supporting IPD. Because BIM can combine, among other things, the design, fabrication information, erection instructions, and project management logistics in one database, it provides a platform for collaboration throughout the project's design and construction. Additionally, because the model and database can exist for the life of a building, the owner may use BIM to manage the facility well beyond completion of construction for such purposes as space planning, furnishing, monitoring long term energy performance, maintenance, and remodeling." (AIA 2007a, p. 10). It also describes BIM as "an evolving technology" but is clear about the fact that "BIM is a tool, not a project delivery method, but IPD process methods work hand in hand with BIM and leverage the tool's capabilities." (ibid.)

Adding further confusion, the placement of BIM in the AIA taxonomy is shown in Figure 3.

Eastman et al. define "BIM as a modeling technology and associated set of processes to produce, communicate, and analyze building models. Building models are characterized by:

- Building components […] that 'know' what they are […].
- Components that include data that describe how they behave, as needed for analyses and work processes […].
- Consistent and non-redundant data such that changes to component data are represented in all views of the component." (Eastman et al., 2008, p. 13).

The National Institute of Building Sciences (NIBS) lists various expansions of BIM. "BIM stands for new concepts and practices that are so greatly improved by innovative information technologies and business structures that they will dramatically reduce the multiple forms of waste and inefficiency in the building industry. Whether used to refer to a product – Building Information Model (a structured dataset describing a building), an activity – Building Information Modeling (the act of creating a Building

Information Model), or a system – Building Information Management (business structures of work and communication that increase quality and efficiency), BIM is a critical element in reducing industry waste, adding value to industry products, decreasing environmental damage, and increasing the functional performance of occupants." (NIBS, 2007, p. 1). It later refers to BIM "as a product or intelligent digital representation of data", "as a collaborative process", and "as a facility lifecycle management tool" (ibid., p. 20).

Discussion

It is outside the scope of this paper to interpret the various definitions and descriptions of BIM –let alone to attempt to reconcile them. They are strong evidence that BIM has different meanings when examined from different professional perspectives. Parties representing these and other perspectives not quoted above do unite on any one project in the Architecture Engineering Construction Operation (AECO) industry and have to agree how to proceed. For participants in this process it then becomes necessary to agree on their own functional definitions.

BIM is still an emerging technology, process, platform, or system; therefore, changes in definitions of BIM are expected, and this applies to many existing terms in the research domain as the knowledge develops with the increasing depth of the research corpus, but also new terms emerging and others losing importance or relevance (Bhatt and Kishore, 2008). Even terms that have been established longer ago may experience shifts in meaning, because language is a living, cultural phenomenon. Therefore, the construction of an ontology is an ongoing process. Some researchers advocate an open approach that allows evolution of an ontology over time (Mikroyannidis and Theodoulidis, 2006; Lin and Chiu, 2008).

Ontology construction

In the literature about ontologies, the predominant paradigm appears to be construction by designers, developers, or domain experts (Horrocks 2008, Lee et al. 2008). There is also research about automation of ontology construction, with examples within our research domain (Turk et al., 2001; Bhatt and Kishore, 2008).

Turk (2001) concludes that the success of automatic construction of a domain ontology may require machine learning from human example: "Our future work will be dedicated to learning about the shared perspective in the same way as the humans did – through interaction with the members of the scientific community. […] In this way, the machine can learn the communities' view and pass on this view onto the new members of the community."

Bhatt and Kishore (2008) conclude "Architectural knowledge is constructed in a series of engagements between the deterministic order of things, and the pure experience of order, it is situated in a series of what Michel Foucault terms as the middle practices. They remain in a tacit, tactical way: left alone, would any machine, from a machine's perspective, reconcile our discipline, | Computer-Aided Architectural Design | with the art of making buildings?"

One of the challenges that Bhatt and Kishore (2008) attempt to address with their research into automated ontology extraction is the slowly progressing, asynchronous exchange in the research community, where arguments in the discourse are exchanged at the pace of the conference and proceedings cycle with responses to published research delivered in other published research on the next cycle, or with some fast-track approach in a different but related conference series; yet, still in consecutive manner moving at the pace of conference submit and review cycles. Automated ontology construction has the potential of tracking knowledge development in the research domain by detecting changes in domain ontology (Bhatt and Kishore 2008, p. 860).

By using CumInCAD as resource, Turk (2001) as well as Bhatt and Kishore (2008) certainly propose the automated ontology construction based on sources largely limited or in close proximity to the research community, i.e. an expert-level community.

However, their conclusions appear to point to an innate contradiction in automating something that is a cultural and, therefore, partially subjective and ultimately very human process.

Proposal

In support of accelerating the discourse cycle for the development of an ontology for the research domain "computational design" within the research community this paper proposes a human-based approach comparable to other community-based knowledge processes, like Wikipedia. In the concrete case of our research community as encompassed by eCAADe, ACADIA, CAADRIA, SIGraDi, ASCAAD, and the CAAD Futures organizations, as well as other overlapping or related research communities like the community around the Design Computing and Cognition conference series, or more generally related single-shot conferences, such an effort has also the potential to enhance the sense of a continuum of research across regions, as well as across focus areas.

A shared ontology would enable indirect as well as direct exchanges between researchers with more experience in the field and researchers with less experience who may be joining the field, for example graduate and post-graduate students, or researchers joining in inter-disciplinary efforts from adjacent or very different fields. An approach to construction of ontologies by domain experts with expandability by non-experts has been demonstrated by Liu and Gruen (2008).

This community has the advantage that many members are deeply vested in education, so that the educational value of such community-developed ontology can be fostered and disseminated. Well-conceived and well-constructed, a human-made ontology has nevertheless the capability to inform machine-based processes, like automatic categorization of digital sources (Horrocks, 2008). It could also serve as a more robust source of reference data for comparison of effectiveness of automated approaches overcoming limitations described by Turk et al. (2001) as well as by Bhatt and Kishore (2008).

Conclusion

The emerging properties of a research domain are a cultural phenomenon which we may not be able to compute with the technologies currently at our disposal. While it certainly is a valuable effort to develop such technologies, it is questionable whether the domain has the luxury and researchers have the patience to wait for this effort's success. Meanwhile, the current deficit of a well-developed domain ontology and the challenges arising from this deficit, may in fact constitute an opportunity to enhance the cultural phenomenon of research communities.

Similar to developments in other areas, this paper proposes to embrace a collaborative community effort to constructing a research domain, accelerating the research cycle while at the same time starting to build a tool that may support education as well as automation of processes related to effective use of ontologies for categorization and analysis.

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