Pursuing an AI Ontology for Landscape Architecture

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Abstract: Technological advancements have become ubiquitous within landscape architecture. One of the latest advancements is in Artificial Intelligence, including techniques such as Machine Learning, Artificial Neural Networks and problem optimization. These advancements have already worked their way into landscape architecture. In this theoretical paper we briefly identify what the state of the art in AI is, as well as its potential and limitations in the discipline. Specifically, we argue for the need to create a disciplinary ontology to make knowledge explicit and shared amongst humans and machines.

Keywords: Artificial intelligence, computational design, landscape architecture practice

1 Introduction

In recent years landscape architecture has pushed advances in design computation and information modelling beyond the building, embedding them into curriculum and professional workflows, and experimenting with design processes such as terrain modelling (HERMANSDORFER et al. 2020, HURKXKENS et al. 2017), monitoring public spaces for design assumptions (ZEIGER 2019), modelling uncertainty in a 'synthetic' ecology (CANTRELL & HOLTZMANN 2014), and reflecting temporality in CAD workflows (TEBYANIAN 2016). The use of computation in landscape design is burgeoning and shows signs of sustained growth in the future (GEORGE & SUMMERLIN 2019). Some landscape architectural researchers and practitioners have begun imagining the potential for a greater disciplinary discourse on computational design and parametricism (CANTRELL & MEKIES 2018), proposing that landscape is a profoundly more complex system than that of a building or singular piece of infrastructure and thus needs to construct a system more responsive to the many factors and contexts in which it is embedded (CANTRELL & HOLTZMANN 2015). Yet because landscape is such a fundamentally expansive medium, the array of possible computational tools to apply to its design is also much more vast than the more manageable scope of something like architecture, and can thus lead to digital overload (FRICKER et al. 2013).

For all the diverse ways designers engage with other disciplines, most simply do not have the time, knowledge, or cognitive capacity to account for the range of intersectional aspects of today's design problems. To this end, there is new discourse emerging around the potential of artificial intelligence to help facilitate such limitations. It includes topics like laying the historical groundwork for AI so as to create better understanding in the profession (ZHANG 2020), proposing machine learning primers and ontologies for landscape design (ALINA et al. 2016, TEBYANIAN 2020), gauging the potential for AI in coastal adaptation design (ZHANG & BOWES 2019), and even envisaging an automated, post-human ecology (CANTRELL et al. 2017). As the trend of AI takes hold in design disciplines, there is an essential need to build a shared language between humans and machines, especially ensuring that assumptions, vocabularies and knowledge are explicit. This paper lays a theoretical foundation for the development of an information science *ontology* in the landscape architecture domain. Ontologies can improve problem solving because they make knowledge explicit, open and reusable by

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AI systems (and humans). The development of a landscape architecture ontology will enable an AI system to more easily gather and synthesize knowledge while elucidating domain assumptions and philosophies of design.

2 Developing a Landscape Design Ontology for AI

2.1 Clarifying the Term Artificial Intelligence

When the term 'artificial intelligence' is presented to a general audience, it is more likely to elicit troubling images from Sci-Fi movies than a basic understanding of AI research (FAST & HORVITZ 2016). Thus, before we delve into the research questions, it is important to understand what AI is, how it works and why it might make us feel simultaneously excited and a little uneasy. The Oxford Dictionary defines Artificial Intelligence as "…computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages." Though the concept of it has been in development for centuries (BUCHANAN 2005, POOLE & MACKWORTH 2010), the beginnings of modern AI computing are often understood to have spawned in 1950 when Alan Turing posited: "can machines think?" and while he soon discovered that they could indeed, the bigger question he came away with was whether or not machines are capable of thinking like humans (TURING 2009). This highlights an important distinction often overlooked by the AI layperson; AI capability is different from AI functionality. Before AI attains human capabilities like abstract thought, empathy, and understanding meaning, it has to master the basic functions that build those capabilities. Functions include effective use of limited memory, reaction to stimuli, and real-time decision making (TECHLIANCE 2020). Some of the latest inquiries into the state of the field claim there are still many barriers to crash before reaching that milestone (MITCHELL 2020).

Nearly every branch of research or application of AI requires creating ontologies, methods, data mining or expert-based learning and developing statistical approaches to facilitate reasoning. In each instance, humans are involved in building and maintaining these systems, but the key defining element is that machines are the curator of learning. This is done through language and computational methods (e.g. statistics) that can amalgamate large datasets and be trained (using humans to fill gaps of learning). For instance, the detection of cancers can be done by allowing a computer to read radiological images and statistically characterize them to identify anomalies (AMERICAN ASSOCIATION FOR CANCER 2018, [1]); learning reinforcement happens when the computer is trained by a human to identify that the anomaly is a cancer. The more images read and correct detections made, the better the statistical models become. In this case reasoning is a statistically based outcome of learned information. However, such outcomes are not possible without abundant data, a clear language, and a reliable set of rules to follow.

2.2 What is an Ontology?

Ontology, philosophically understood, is the study of the nature of being or existence. When applied within the context of computer science and artificial intelligence, an ontology is a noun rather than a state; a formal structure of definitions, components, concepts, entities and the relationships between these that work to form an AI reality (CIMIANO 2006). Thus, creating an ontology necessitates the creation of language (syntax and semantics), rules, knowledge and their relations (POOLE & MACKWORTH 2010). Human knowledge is gained by an experiential and intentional process of being in existence (e.g. a radiologist seeing imagery of cancer and discovering that cancer is present). Just as we each gain knowledge as a result of our learned language and experiences, an AI system must also have an explicit structure of language and experiences in order to learn (e.g. exposure to statistical properties of cancer in an image). The act of building an ontology can be likened to an act of teaching definitions and relationships between phenomena (or *things*). Teaching definitions, however, do not always provide critical nuance and context; instead, that is learned by process.

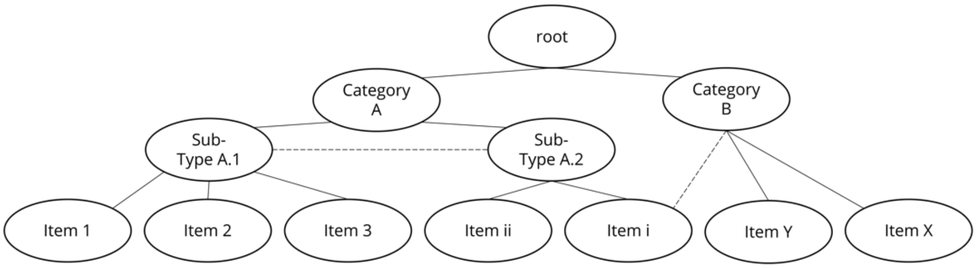

Fig. 1: Abstraction of ontological framework showing nested hierarchies and illustrated relationships (dashed lines). In a developed ontology, each oval would have a definition including syntax, unit, description, properties and synonyms.

For AI to develop it requires access to an ontology, which is often implicitly created by the programmer at the time of development. When programming an AI system, programmers develop classes, functions, variables, units and naming conventions in code. The creation of these is often done within a well-defined conceptual framework that has multiple degrees of formality from informal naming conventions to predefined reserve variables, functions and constants. An ontology is a formal way to express definitions and linkages between terms. It also enables AI systems and human coders to use, reuse, redefine and expand upon the ontology. The building blocks of an ontology often begin through an abstraction of key concepts, items, categories, et cetera, that are depicted through a hierarchical structure, as shown in Figure 1 (a practical example is shown later in Figure 2). The hierarchy provides an explicit rule of how *things* are connected, enabling the system to learn these connections and be connected to other published ontologies. For instance, a landscape architecture ontology could reuse a plant ontology developed by biologists, or a geoscience ontology that provides properties of soils, minerals and geophysical history. A relationship between these three ontologies means that an AI system would instantaneously have access to knowledge from each of these systems, analogous to Neo's rapid skill acquisition in *The Matrix.*

Crafting an AI ontology is at its core an act of assemblage. Rather than working from a tabula rasa, the program is nearly always built by explicitly remixing existing frameworks and applying them to problems in new contexts (JOHNSON-EILOLA & SELBER 2007). Such reproduction is considered best practice and often even a requirement if different applications are to communicate with one another (NOY & MCGUINESS 2001). A work of landscape architecture is no different. A site with all its components is shaped physically, culturally and functionally by remixing known ontologies of design processes and applying them to the problem at hand. Yet, understanding of these ontologies is markedly more implicit in practice than we often realize. For example, when a human designer composes the planting design for a pocket park, they generally go through the motions of analysing site conditions, developing the planting concept, selecting a plant palette (perhaps organizing it using the usual categories trees, shrubs, forbs and grasses, etc.), laying out a configuration for the selected plants in plan view diagram, and making a schedule for the implementation of the design. If the average entry-level designer were instructed to carry out these steps, the end goal would seem relatively clear. However, for an AI the goal would need to be more clearly defined. For instance, the AI needs to know what plants are, how to categorize them, what properties are important and what site conditions they thrive in. In this case, the fundamental questions of what, how, where, when, and why are procedural rather than theoretical.

2.3 Translating Practice into Language: The Question of an Ontology for Landscape Architecture

Developing a landscape architecture ontology may be a unique challenge because it hardly fits into the structured framework of a definition. This happens because the design process is culturally influenced and steeped in qualitative interpretation. Thus, a general glossary of landscape architecture terms would need to include cultural nuances in the meaning of such terms in different places as well as the interdisciplinary ways such terms can be measured (HERRINGTON 2013). John Stilgoe's "What is Landscape?" (2015) tackles such a task by revealing the complexity embedded in the attempt to understand what landscape (and therefore, landscape architecture) is. His tracking of the etymology of the word landscape across cultures and ages gives a sense of the vastness and extent of such nuances.

However, despite such hardness in defining landscape in a non-reductive way, such activity exists, and is practiced daily by designers around the world. How is that possible? As researched extensively in the field of cognition and cognitive science, the design process relies on unwritten knowledge, something practitioners learn by experience without referring to extensive verbal codification. Donald Schon used to call it "reflection in action" (SCHON 1983). As mentioned, AI requires an ontology, a syntax or a clear definition of the activity in order to automate it. Considering the complexity of the landscape architecture practice, what would be the ontology of landscape architecture, and how does one embark on the process of developing it? As we consider the development of a landscape architecture ontology, we must also explore our existential framework as designers - are we unique, a mere construct of other existing ontological domains or some combination thereof? If we assume disciplinary uniqueness, a direct adoption of other ontologies may not be compatible with our own. The ontology of landscape architecture must then include terms, associations and concepts endemic to practice and not just those borrowed from others. Thus, the *pursuit of an AI ontology for landscape architecture*, that is comprehensive and interdisciplinary, needs to be carefully crafted for AI functionality to be fully integrated into practice.

3 Example Ontology Using Fresh Kills Park Master Plan

With this understanding, we propose assembling a more explicit and programmable ontological structure for landscape architecture. One that compiles the already rich and diverse frameworks of the discipline and defines them procedurally so that the all but inevitable creep of AI applications into landscape practice evolves with, rather than supplants the role of the designer. To demonstrate the complexity of this task, we construct a sample ontology for one section of a well-known, well-documented work of landscape architecture: the Fresh Kills Park Draft Master Plan. The plan was developed over five years following the closing of New York City's Staten Island's Fresh Kills Landfill in 2001. The plan document continues to guide the phasing of the project today. Its conceptual framework, known as Lifescape, has become one of the most highlighted and critiqued poster children of the Landscape Urbanist movement, whether for its socio-ecological implications as a large park, its conceptual centring on cutting edge theories of ecological succession, or the role it played pushing the discipline into a new chapter (BEARDSLEY 2007, CORNER 2006, WALDHEIM 2016). Lifescape is defined in the report as the following:

> "Lifescape is an ecological process of environmental reclamation and renewal on a vast scale, recovering not only the health and biodiversity of ecosystems across the site, but also the spirit and imagination of people who will use the new park. Lifescape is about the dynamic cultivation of new ecologies at Fresh Kills over time – ecologies of soil, air and water; of vegetation and wildlife; of program and human activity; of financing, stewardship and adaptive management; of environmental technology, renewable energy and education; and of new forms of interaction among people, nature, technology and the passage of time."(FIELD OPERATIONS 2006)

This narrative statement is both broad and encompassing. It holds within it a variety of terms and concepts that would create a vast network of possible ontologies spanning far outside the scope of this exercise. For our purposes, we will focus on deriving a hierarchal ontology for just one aspect of the Master Plan which we consider to be a major driving force of the Lifescape concept, the Landscape and Habitat Plan; more specifically, the planting palette of that plan (see Draft Master Plan, Section 2.13, [2]). In it, there are three major landscape types proposed (wetlands, grasslands, woodlands) each with its own subsets of habitat types (e.g. salt marsh, fens, eastern dry prairie, birch thicket, etc.). For each habitat type, a palette of plants was selected to fit the priorities of low maintenance and ecological appropriateness.

In Figure 2, we have taken some of these elements and organized them into the beginnings of a legible hierarchy where a thing is the root, habitat types are the categories and subtypes, and the plants the items. This framework would then be discretized using descriptors called object properties, which delineate the relationships within the hierarchy as well as those between different sets of hierarchies. An AI would learn from this ontology, for instance, that a Morainal Oak plant community is a subtype of the habitats which make up the landscape category Woodland and is comprised of trees such as oaks, beeches, and hickories (with specific species denoted) and shrubs like arrow wood and spice bush. These connections might utilize a property like 'is part of' or 'develops from' to give meaning to their place in the hierarchy. Now that this habitat type is explicitly defined, it can be reused, modified, augmented and adapted to other design opportunities by an AI. Yet, it also provides benefits for human users to more quickly observe and understand the elements that make up this specific habitat type. This same process is done for every habitat type, where some plants are also "Part of" other habitat types.

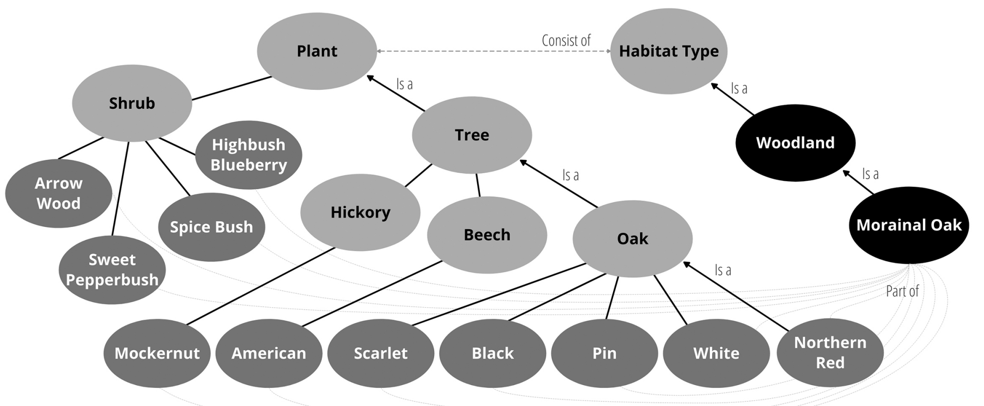

Fig. 2: Abstraction of ontology for Morainal Oak Woodland from the Fresh Kills Park Habitat Plan. Solid lines are hierarchical, light grey dashed lines are relational.

While assembling this habitat ontology, it quickly becomes clear that, given the available information in the master plan, it can only apply to that specific context and that the context itself is sparsely defined. The text provides no adjacent ontological contexts with which to associate it because it assumes an implicit understanding of its components e.g. the landscape architects assume the readers can reasonably know what a landscape is, what a plant is, what a tree is, where each these come from, how they relate to other examples of the same and what makes them specifically relevant to their prescribed type. A machine cannot know these things unless it is taught by a human expert (even through the reuse of other ontologies). Such an exercise offers an opportunity not only to lay out the terms of AI's engagement with practice but also to self-reflect and clarify what we understand practice to be and how we think it sits in relation to other disciplines.

4 Reflections: Limitations, Futures, Expectations

We recognize that an effort to assemble an entire ontology of landscape architecture in one paper or proceeding would be futile. Our intent is merely to initiate a call to attention toward the need for an explicit definition of terms and relationships of things within the landscape architecture domain. As digital landscape architecture professionals, we can be leaders in the AI-LA dialectic and lead the way in constructing language, skill sets, ethics, and best practices for environmental design. It should be emphasized that an appeal for further ontological structure in our digital practice does not diminish current or former structures of landscape practice; in our view, adapting the programmer perspective of reusing and expanding existing ontologies (e.g. building our framework utilizing the vast and well-established repositories in venues like AberOWL or GitHub and then building it right back into those repositories so it can be added to by the community at large) only deepens respect for them and affords an opportunity to better understand their nuance.

This is not a modernist call for historical erasure, nor is it a postmodernist plea for refracting our practice into endless language games. It is a challenge we extend to all in the discipline to have more organized and direct discourse on the application of artificial intelligence. The intent of this process is not to facilitate reductionism, on the contrary discourse facilitates clarity of our own language. Further, while AI in landscape architecture may be perceived as nascent within practice, if we do not lead this discourse we risk letting it be defined by those who lack knowledge of our practice and thus lack of embodiment of our language. Rather, taking the reins on developing an ontology enables landscape architects to facilitate control of our own language evolution. A clear, yet flexible structure of language allows us to challenge and anticipate the impending pervasion of AI into the industry rather than be blindsided by it. To this end, control of language begets control of agency guiding the design of new AI tools that take our work to places never before imagined, while still governing the creative process and avoiding a banalization of the landscape designer's role. This inevitably means reassessing the creative process itself and our role in it.

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