Josh Eastburn

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The Sciences of the Artificial:

A Critical Analysis of CS/SE-Related Themes

At the heart of The Sciences of the Artificial is the argument that there exists a body of knowledge within but apart from the natural sciences, called the artificial sciences. The purpose of the book then is to "attempt to explain how a science of the artificial is possible and to illustrate its nature [14:xi]." Of the seven essays included, I studied chapters one, three, five, and seven, which deal with, respectively, understanding the natural and artificial worlds, the psychology of human cognition, the science of design, and the architecture of complex systems.[1] Keeping in mind the age of this book (originally published in 1969), the view I want to take on these essays is not only an analysis of the central thesis, but on its applicability to computer science and software engineering now.

The Author and His Work

The author, Herbert A. Simon (1916-2001), was well-equipped to discuss themes related to computing as well as the host of other areas covered in Sciences [1,2]. The breadth of his work has been called "Renaissance-like [3]." A Nobel laureate and professor at Carnegie-Mellon University since 1949, his research also earned him the 1988 John von Neumann Theory Prize [3] and the A.M. Turing Award [4]. He was considered a founder of, and expert in, artificial intelligence, and was influential in the formation of CMU's School of Computer Science (among

1 Please note that I read the 2nd (1981) edition of The Sciences of the Artificial. An important difference between the 2nd and 3rd editions is the addition of a new chapter in the latter. Chapter 8 in the 3rd edition is chapter 7 in the 2nd.

others). The thread relating all his work was an interest in human decision-making and problem-solving, and their implications for society [1].

Central Thesis & Ideas

Artifacts and artificial systems, as contrasted with natural systems, are those that are shaped by environment, specifically by man's purposes [14:6], rather than by natural law [14:ix]. The inherent question, says Simon, in establishing a science of the artificial is whether it is possible to say anything meaningful about a system whose expected behavior is contingent upon the characteristics of the system in which it resides [14:x]. Can we speak descriptively about these systems as a body, and do we have a way to relate them to the natural systems we understand [14:6]?

To answer this, Simon presents a paradigm that includes the external environment in the study of the inner-workings of the artificial system it contains. He views the artifact itself as an interface between the two systems [14:9], focusing on a description of its function and goals rather than its internal workings [14:12]. The rest of his essays explore how this idea can be applied to our study of a wide range of artificial systems: economics, the human mind, design, city planning, computing, etc. Chapter 7, "The Architecture of Complexity," expands on this idea by arguing that many apparently complex systems can be viewed as a hierarchy—or more appropriately, perhaps, a collection—of subsystems [14:196].

Criticism

One reviewer suggests that the ambiguous nature of systems, the prevalence of hierarchy in much of Simon's work, and its usefulness as a heuristic may have lead him to overgeneralize [6]. One important point is that Simon discusses artificial systems under the restriction that they are man-made [14:6]. In discussing complexity, however, he doesn't observe that same restriction [14:198, 202-205]. This is potentially significant because it is entirely possible that complex human systems favor hierarchy while the rest of creation does not. [6] goes on to point out that many systems, human and natural have not evolved in the way Simon describes, and that modularity, in some instances, is introduced after the fact.

Another critic points out the possibility of projection errors—being unintentionally focused on viewing the subject through a certain lens—and, perhaps as with complexity, viewing psychology as he already imagines to be [7]. Interestingly, at the same time that Simon was publishing Sciences, Thomas Kuhn was publishing a book about the inability of scientists to be theory-neutral in their observations [9].

This might explain the eerie feeling that Sciences gave me at times. Simon's writing style makes this book surprisingly accessible given the level of discussion and the broad range of subject areas, but at the same time, I'm at a disadvantage when reading it because I am not a psychologist, city planner or logician. Some sections seem to lack supporting citations or cite mostly Simon's own work, leaving me with the feeling that I'm missing something. As one critic put it, "He is a master craftsman at framing his arguments—although his conclusions may seem a little too pat for some tastes [12:429]."

Others interested in the study of design have taken Simon to task for what they call a linear-minded, academic approach to professional practice. These emphasize the role of the designers disciplined thoughtfulness about each problem[2], and accuse Simon of trying to replace that process with the rigid analytical methods he had seen in other fields [8,11]. Recently, though, [15] has shown such accusations to be misrepresentations of Simon's argument, usually based on an incomplete understanding of his methodology.

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2 See [13] for a recent and insightful study on expert approaches to such ill-defined problems.

Certainly, then, Simon has his critics, and yet the ideas in Sciences are largely credited as profoundly influential, even foundational, in the areas of organizational science, economics, cognitive science, artificial intelligence, design and probably others [3,6,7,12].

Application to CS/SE

Software systems are dealt with in a hierarchical fashion even at a very low level, and have been well before object-oriented languages became popular [16]. As principles of information hiding and data encapsulation have become more prevalent, software engineers pay more attention to properties of the resulting hierarchy like cohesion and coupling [17]. Simon's argument of the near-decomposability [14:209] of hierarchical systems is therefore true by design in many software systems. Although different programming paradigms might differ on how to separate the various functions of a software system [5], or even if that separation is determined by the need to fit the software system to a particular external environment (e.g. distributed computing), the hierarchical nature seems inescapable. Simon sees this as a natural and effective approach to the design of artificial systems [14:148-149].

Furthermore, his discussion on the science of design touches on issues now central to software engineering. He suggests the importance of such practices as user-involvement in the design process [14:150-151]. Additionally, he foresees the continuing difficulties inherent in problem representation, and therefore the need to develop and teach effective representational schemas [14:153-155]. He also suggests the concept of requirements adjustment [14:147-148,15:64] (a la Parnas & Clements [10]) and the need to *satisfy* requirements, not to find an optimal solution for them. In fact, he states that it is likely impossible in many situations [14:138-139].

We can better understand the nature of what we do by application of his ideas. For instance, we often discuss software design and use in terms of function—of what it's supposed to do.[3] That is not to say that non-functional requirements are not taken into account, but Simon would probably see those as requirements that the external environment places on the design of the artifact-to-be. This is part of what Simon calls the limits of adaptation of the inner environment of an artifact [14:16]. Users and designers confront that all the time in the form of Minimum System Requirements.

Conclusions

Chapter 3 discusses some theories about the structure of the human mind and causes me to wonder if a serial, list-based engine (as Simon suggests the mind to be) wouldn't favor the structure and near-decomposability of hierarchy. Would hierarchy appear to be inherent in almost everything if only by virtue of the fact that the mind can't conceive of anything else? Am I safe in saying that we can look to computer science for some idea of what kind of systems serial, list-processing engines have produced?[4]

Nevertheless, the fact that so many of Simon's ruminations on the basic science of design, which branches far beyond computing, now show up in everyday practice in software engineering (not to mention other fields) demonstrates the strength of his ideas. One critic put it this way: "The total thrust of his thought, across many interdisciplinary boundaries, makes one wonder if, indeed, he may not be on to something important [12:428]." But whether Simon was on to something important or not, his ideas seem to have found application in at least one science of design.

3 Making it do that, is another issue.
4 Or is that "the systems that serial, list-processing engines have produced using serial, list-processing engines"?

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