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Position Paper
Science of Design: Software-Intensive Systems

According to the call for position papers:

> A design is the product of a process of *designing* of that desired artifact, system, process. Moreover, the design itself is an artifact and is designed.

Yes. But what kind of process? What kind of artifact? From the classical engineering-design perspective, one tends to think of the design process as a more-or-less self contained intellectual endeavor pursued by an individual designer or a design team interacting with the physical world. The resulting design is a more-or-less self-contained artifact sufficient to generate instances of the "desired artifact, system, process." But there are a variety of sociological perspectives, notably the "social construction" school, that see the design process as almost entirely a matter of social interaction, and the resulting designed artifact as preeminently a "social construct." In some formulations, indeed, one is left wondering whether the laws of physics (or relevant external constraints in general) play any role at all in design. Clearly, any well-developed science of design must take seriously the problem-solving character of the design process as well as understand the ways in which that process reaches beyond the individual designer or design team.

Toward this end I advocate a perspective informed by *evolutionary economics*. *Evolutionary social science* may in fact be a better term, since one of the main objectives of this approach is to account for and to understand complex social formations like organizations and institutions. Although the evolutionary perspective I'm advocating dates back at least to the work of Adam Smith, its present-day incarnation emerged out of the "invisible college" of economists and kindred spirits who study innovation and technological change, and it has informed – and learned from – a wealth of historical and analytical studies of the development of technology. Rather than portraying social outcomes as the result of a process of optimization over known and given variables, the evolutionary approach sees such outcomes as the result of the evolution of human knowledge embodied in rules, routines, institutions – and artifacts.

On the one hand, the evolutionary approach connects firmly to the engineering-design perspective. Important theorists of design like Christopher Alexander and Herbert Simon illustrated their ideas with examples from both the design of artifacts and the evolution of biological structures. There is good reason for this: evolution is a design process. And the relationship between evolution and the problem-solving conception of design is quite clear. As the late Stephen J. Gould put it, a non-tautological evolutionary explanation demands showing how a structure meets "an engineer's criterion of good design." An evolutionary account thus insists that designs are ultimately solutions to problems posed in part by the non-human environment, even if those problems are often unarticulated and their solutions frequently non-conscious.

On the other hand, however, the evolutionary perspective is also social. It is social in the sense that it is not inconsistent with accounts of human interaction and group cognition in the design proces. More importantly, however, it is social in the sense that it directs our attention to the ways in which human designers always rely fundamentally on "social" knowledge. Design is not a self-contained process in which a designer creates design knowledge *eh nihilo*. Rather, design is always tinkering: it is the recombination of existing bits of knowledge that were created in other contexts and stored in forms that are sometimes explicit and sometimes tacit, sometimes codified and sometimes embodied in practice or artifact.

One important area in which the evolutionary and engineering-design perspectives overlap is in the theory of modular systems. Complexity is of course a central issue in the theory of design: as Frederick Brooks famously pointed out, the benefits of the division of labor can be overwhelmed by the costs of communication among autonomous units. The theory of modular (or decomposable) systems suggests that a clever decomposition of the system can minimize communication costs. From an evolutionary perspective, however, modularity has another benefit: it allows rapid learning through the recombination of elements – and thus permits the use of large amounts of design knowledge beyond the ken of any single design team.

Personal qualifications

Although I have inhabited an economics department for more than 20 years, my original training was in physics (B.A. Williams 1974, physics and English literature; M.S. Yale 1975, astronomy) and systems engineering (Ph.D. Stanford 1981, Engineering-Economic Systems). One of my principal research tracks has been to theorize (that is, to think systematically) about organization and technology. I was an early (and arguably influential) contributor to the literature on modular systems, which has since burgeoned into a major research area in management and technology studies. Another – complementary – focus of my work has been the economic history of technology. I have written significant histories of such industries as computers, semiconductors, semiconductor equipment, and software. My history of the microcomputer industry won the Newcomen Award as the best article in *Business History Review* in 1992.

Some (possibly relevant) publications.

Garud, Raghu, Arun Kumaraswamy, and Richard N. Langlois, eds. 2002. *Managing in the Modular Age: Architectures, Networks and Organizations*. Oxford: Blackwell.

Langlois, Richard N. 2002. "Modularity in Technology and Organization," *Journal of Economic Behavior and Organization* **49**(1): 19-37.

Langlois, Richard N., and David C. Mowery. 1996. "The Federal Government Role in the Development of the American Software Industry: An Assessment," in David C. Mowery, ed., *The International Computer Software Industry: A Comparative Study of Industrial Evolution and Structure*. New York: Oxford University Press.

Langlois, Richard N., and Paul L. Robertson. 1992. "Networks and Innovation in a Modular System: Lessons from the Microcomputer and Stereo Component Industries," *Research Policy* **21**(4): 297-313.

Lavoie, Don, Howard Baetjer, William Tulloh, and Richard Langlois. 1993. *Component Software: A Market Perspective on the Coming Revolution in Software Development*. Special Research Report, Patricia Seybold Group, Boston, April.