Circuit Engineers Doing Biology: A Discourse on the Changing Landscape of Scientific Research

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Abstract

In specious attempts at classifying science, disciplines sometimes are branded as "hard" or "soft" according to the perceived mathematical rigor and objectivity of their endeavors. The degree of hardness decreases from the physical sciences (rock-hard and objective), to the biological sciences, to the social sciences (soft and subjective). There is also a presumed food chain: the "pure" sciences and mathematics *produce* new understanding; the "applied" sciences and engineering *consume* it.

Such characterizations are vacuous. Consider that statisticians in the social sciences engage in sophisticated mathematics and that theoretical physicists apply intuition to thought experiments. Increasingly, disciplines across the scientific spectrum are being hardened with quantitative analysis: data, observations, models – everything is stuffed into a computer and analyzed. Also, engineering methods for design are being used in a deliberate way to *validate* new science. As Richard Feynman stipulated, "If I can't create it, I don't understand it." Understanding is achieved by constructing and testing simplified systems from the bottom up, teasing out and nailing down the fundamental principles in the process.

In this talk, I'll describe this landscape as I see it – through the narrow lens of the research activities in my lab. These encompass projects in the design and verification of digital circuits as well as in synthetic and computational biology. A broad theme is the application of computational expertise from the former (circuit design) to analysis and design problems in the latter (biology). A specific theme that cuts across both domains is constructing and deconstructing probabilistic behavior. In the biological realm, we are designing biochemical pathways that produce different combinations of molecular types according to *programmable* probability distributions. This gives us the ability to fine-tune the response – akin to hedging with a portfolio of investments. In the engineering realm, we are designing digital circuits that process "zeros" and "ones" probabilistically. This is a promising strategy for coping with the randomness that occurs due to noise and glitches as circuit components are scaled down to nanometers in size (that's down to *billionths* of a meter). In both realms, the tools of our trade are neither hard, nor soft, nor applied: rather, they are analytical, conceptual, and computational.

I'll also take a cursory survey of the landscape as it might be seen through the wide lens of public interest in science. I'll discuss the ethical and security concerns swirling around research in synthetic biology; the social climate of research in biology vs. engineering vs. mathematics; and the study of circuit design practices as a window into the potential achievements and limitations of human cognition.

Marc Riedel joined the faculty of Electrical and Computer Engineering at the University of Minnesota in January, 2006. He received his PhD and his MS in Electrical Engineering at Caltech and his BEng in Electrical Engineering with a Minor in Mathematics at McGill University. He has held positions at CAE Electronics, Toshiba and Fujitsu Research Labs.