Book Review | *The Nature of Technology: What It Is and How It Evolves*

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Brian Arthur begins his book with a commentary on the dearth of useful literature on the nature of technology: “Technology in fact is one of the most completely known parts of the human experience. Yet of its essence – the deep nature of its being – we know little” (13).

I echo his frustration and applaud his resolve to make a contribution. The philosophy of technology has either been spun out into realms where the concrete is foreign and unwelcome, or summarily dispatched as a pointless exercise beneath the notice of movers and doers in the real world.

Arthur attempts to find middle ground in this book, understanding the philosophical implications of how we manipulate our world through technology and extrapolating this into something that is both thoughtful and useful. While the book displays some fundamental flaws, his efforts open up some interesting avenues for further practical reflection.

Over the past 30 years, Arthur has observed ways in which it seemed technology created itself. Eventually encountering the work of Francisco Varela and Humberto Maturana, he became convinced that technology was autopoietic, or self-creating (2). Such a conclusion required him first to understand the mechanisms of the invention and evolution of technology – how new discoveries are made and how change takes place in technological systems.

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As his ideas about technology took shape, he realized that technology was recursive, that each individual technology is the product of other earlier ones, and that new technologies often emerged not from new discoveries but from the recombination of existing technologies into new systems. Thus his favorite source of information became historians of technology, as they were most interested in the details of how technological systems emerged and changed.

Arthur is clear up-front about his intentions. His book is not about the perils or promises of technology, nor is it a review of the literature. He tries to be precise about the terms he uses, to minimize confusions, and for the most part he succeeds. Before discussing my disagreement with his definitions and therefore with his conclusions, however, Arthur’s argument needs to be laid out in the terms he presents.

To summarize in his own words: “Technology is what separates us from the Middle Ages; indeed, it is what separates us from the way we lived 50,000 or more years ago. More than anything else technology creates our world. It creates our wealth, or economy, our way of being. What then is this thing of such importance? What is technology in its nature, its deepest essence? Where does it come from? And how does it evolve?” (10).

For Arthur, talk about the evolution of technology evolves requires a careful choice of terminology: “The word ‘evolution’ has two general meanings. One is the gradual development of something, as with the ‘evolution’ of ballet or the English madrigal. I will call this evolution in the narrow sense, or more usually ‘development.’ The other is the process by which all objects of some class are related by ties of common descent from the collection of earlier objects. This is evolution in its full sense, and this is what I will mean by evolution” (15).

He is careful to say that he does not find a Darwinian mechanism in the evolution of technology. Instead, “technologies somehow must come into being as fresh combinations of what already exists... Novel technologies must somehow arise by combinations of existing technologies” (19). Picking up on the work of earlier thinkers like Joseph Schumpeter as long as a hundred years ago, Arthur concludes: “The overall collection of technologies bootstraps itself upward from the few to the many and from the simple to the complex. We can say that technology creates itself out of itself” (21). He calls this mechanism “evolution by combination, or more succinctly, combinatorial evolution” (22).

The argument he proposes toward a theory of evolution for technology has three fundamental principles. First, “all technologies are combinations.” Second, “each component of technology is itself in miniature a technology.” And third, “all technologies harness and exploit some effect or phenomenon, usually several” (23).
One of the strengths of Arthur’s approach is its dynamic representation of technology. Far from being limited to or circumscribed by its status as a collection of objects, technology is open-ended, changing and adapting from what it was into some new state:

Modern technology is not just a collection of more or less independent means of production. Rather it is becoming an open language for the creation of structures and functions in the economy. Slowly, at a pace measured in decades, we are shifting from technologies that produced fixed physical outputs to technologies whose main character is that they can be combined and configured endlessly for fresh purposes. Technology, once a means of production, is becoming a chemistry. (25)

In order to cut through what he calls “the muddle” of competing definitions of technology, Arthur asserts three of his own. First, “a technology is a means to fulfill a human purpose.” Second, technology is “an assemblage of practices and components.” Third, technology is “the entire collection of devices and engineering practices available to a culture,” akin, he says, to what Kevin Kelly calls “the technium” (28).

Arthur emphasizes the constituents of technology, developing the idea of its structure as a kind of anatomy, verging on both morphology and physiology as he explains how the hierarchical structure of parts and related functions is recursive. This allows him to avoid some of the problems with understanding technology in static terms, as recursiveness is inherently dynamic.

Unpacking his definitions, Arthur reveals that technology as “means to fulfill a purpose” is more accurately depicted as “a collection of phenomena captured and put to use” (50-1). While there are no “neat genetics” to technology, he proposes that, “phenomena … are the ‘genes’ of technology” (53). Phenomena – setting aside whether some might be created – are put to use, used for some human purpose, by the technology we wield.

Realizing the likely contrarian response to this portrayal of some of his “scientific” readers, he clarifies his point by saying “science forms from technologies: from instruments, methods, experiments, and explanations. These are the sinews of science. I am not saying – emphatically not – that science is the same as technology. Science is a thing of beauty in itself” (65). Waxing eloquent about the nature of science, Arthur swims upstream against the philosophy, history, and sociology of science in his romanticized depiction of its difference from technology, revealing more about the assumptions underpinning his whole enterprise than about science itself.
Moving from parallels of the genetic language of technological systems to their representation in terms of how a language functions, Arthur further depicts technology as a Heideggerian series of parts and tools ready to hand for our use in the construction of new combinations and designs. He talks about technology in terms of domains, clusters of technologies that depend on the particular use of certain design elements and components. Technological change can take place when the system is “redomained,” that is, when new parts are incorporated with old ones in rethinking the cluster to capture a new phenomenon or to fulfill some recognized need.

Social, cultural and historical periods may be defined either in terms of the domains of technology that characterize them or which they create. Further slurring together his definitions and distinctions, Arthur then introduces the idea of a “grammar” in a domain, “the principles that determine its allowable combinations” (75). “A domain’s grammar determines how its elements fit together and the conditions under which they ‘fit’ together. It determines what ‘works.’ In this sense there are grammars of electronics, of hydraulics, and of genetic engineering” (76).

This leads to the second part of the book, in which Arthur weaves together the “two motifs of technologies adapting by changing their internal parts and of novel structures coming about through fresh combinations” (89). He reminds the reader that his “main theme … is that technology evolves by combining existing technologies to yield further technologies and by using existing technologies to harness effects that become technologies” (89).

Turning to innovation, Arthur in effect derives a model of technological development through problem solving, such as in engineering, that parallels Thomas Kuhn’s caricature of normal science and the anomalies that lead to scientific revolutions. When existing methods, tools, and components of technological systems are insufficient to solve a particular problem, these all may get reworked, repurposed, “redomained,” in such a way that the problem is able to be solved. This perhaps will result in some new technology. Once we have “the thought,” then the means by which it is expressed depend on what is available; if there is nothing adequate to express the thought, then we find new ways or means of accomplishing this. In other words, “standard engineering contributes heavily to innovation. Standard engineering learns” (101).

Similarly, when it comes to invention, something comes from something, not from nothing. “At the creative heart of invention lies appropriation, some sort of mental borrowing that comes in the form of a half-conscious suggestion” (115). Once that concept is in place, he says, standard engineering takes over and finds the means to express the concept or solve the problem that its expression requires.
As a result of such deliberate development, even if its timing is chaotic, “all inventions are supported by a pyramid of causality” that means “an invention tends to show up when the pieces necessary for it, and the need for it, fall into place” (125).

Therefore, he concludes: “The mechanism is certainly not Darwinian; novel species in technology do not arise from the accumulations of small changes. They arise from a process, a human and often lengthy one, of linking the need with a principle (some generic use of an effect) that will satisfy it” (129).

Arthur then returns to his early thoughts about technology and to the concept of “structural deepening.” Simple technologies become more complex as internal elements are replaced, allowing a better or more efficient solution to whatever identified problem.

For a variety of reasons, however, novel technologies are not readily adopted. He claims our general reluctance for new things leads to “adaptive stretch,” finding ways to stretch old technologies to cover new situations until such a response is impractical and innovation (or evolution) occurs.

When it comes to the evolution of technology, Arthur returns to the language of domains. Innovation takes place “when people are faced by problems – particular, well-specified problems” (164). Development results, as existing components of systems are realigned for better solutions. Evolution in technology, however, takes place when “the whole of technology – the collection of artifacts and methods available to a society – creates new elements from those that already exists and thereby builds out” (165).

In chapter 9, “The Mechanisms of Evolution,” Arthur elaborates on his understanding of autopoesis in technology, how it is self-creating. It is not just about technologies creating technologies, he says, “but also of technologies creating opportunity niches that call forth technologies.” Human as well as technical needs can also create such “opportunity niches,” he says, and the “bootstrapping” process then works its way upward (176).

The result of this self-creating process he calls “combinatorial evolution,” which is about “things creating novel things by combinations of themselves” (187). Taking the analogy further, he says technology “is a living webwork that weaves itself out of itself.” He means, in a literal sense, that technology “is indeed a living organism. But it is living only in the sense that a coral reef is living. At least in this stage of its development – and I for one am thankful for this – it still requires human agency for its buildout and reproduction” (189).

In the next-to-last chapter, Arthur offers a means of managing the self-creating process of technological evolution. He sees the economy – as the arena where needs, desires and
problems are expressed and their relative importance determined – as the mechanism by which choices are made. Economics therefore becomes a kind of score-keeping, a way of setting priorities for what problems are to be solved next.

The last pages take the reader into a brief exploration of Heidegger’s “The Question Concerning Technology,” and the ambivalence Arthur noted at the start about the role technology plays in our lives. Technology both directs our lives and serves us, and this duality – what is there beyond our control and what is there by our own desire – creates anxiety that is manifested both consciously and unconsciously in our attitudes and decisions. While he offers little more here than passing commentary on some significant questions about technology, Arthur’s conclusion – that it is an integral part of what makes us human – is a cautionary reminder after all his claims about its autonomous character.

This notion of autonomous technology encapsulates my concerns with Arthur’s approach.

A fundamental flaw is reflected in an early quotation from the book: “We are caught between two huge and unconscious forces: Our deepest hope as humans lies in technology; but our deepest trust lies in nature. These forces are like tectonic plates grinding inexorably into each other in one long, slow collision” for “technology is steadily creating the dominant issues and upheavals of our time” (11).

Technology has come alive, paralleled here to nature and effectively in opposition to it. While “nature” is itself a human creation and much work has been done on what we mean when we use the term, it exists separately from people. Technology does not have the same roots in the natural world around us. It is not autonomous, nor is it alive and separate from the humans who do the choosing and using of it.

Arthur’s reification of technology – giving concrete and real qualities to something that is abstract – is a mistake. A very different perspective emerges from instead seeing technology in terms of knowledge, as instrumental knowledge and its practice.

Technology is in our heads, not in our hands. It is a product of humans making choices for reasons that, in their turn, reflect certain values. Every culture has the technology it wants and needs, reflecting the values it collectively feels the most important, within the environmental and historical constraints that are present at a particular time and place.

Arthur’s description of the evolution of technology is therefore interesting, but flawed. Technology does not itself evolve; it develops and changes to mirror the different choices that humans make for different reasons, in different circumstances, than they did before.
Technology as “force of the universe” talk is misguided and unhelpful, reflecting the problems inherent in Kevin Kelly’s view. This view of technology disempowers people; it allows us to sidestep our responsibility for making the choices that have in turn created the world in which we live.

We need to be empowered to make other and better choices, not mystified by wonder at the tools we have ourselves chosen to make and wield. Behind any tool is the human mind that created the idea for it, shaped it, framed it and made it into something that could be used.

Thus while I can see a variety of ways, as an historian, to apply Arthur’s framework for technological change and development to the emergence and alteration of types of technology, I finish his book feeling no closer to understanding “the nature of technology” he had hoped to address.

Technology and nature are not in opposition, nor is it a question of our hope in technology and our trust in nature. It is our values, what lies behind the reasons we offer in making certain choices and not others, that create both the threat and opportunity. Veiling our choices behind the inscrutable visage of a reified technology is dangerous, because we are hiding from our own eyes the pragmatic, necessary and possible choices a sustainable future requires.