Leslie Valiant

PROBABLY APPROXIMATELY CORRECT

Nature's algorithms for learning and prospering in a complex world

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Alan Turing is commemorated in Manchester's Sackville Gardens as "father of Computer Science, Mathematician, Logician, Wartime Codebreaker, Victim of Prejudice". The centenary of his birth in 2012 provided the occasion for a public coming to terms with the last of these. The significance of the first remains difficult to appreciate. One reason for this is that computing machines have so transformed our lives as to make their absence hard to imagine. A more fundamental reason is that Turing's fathering of computer science is hard to comprehend without some knowledge of the mathematical work by which it was accomplished.

Turing's work gives us a way to think about any scientifically explicable behaviour whatsoever. That is why his negative theorem – that some functions are uncomputable – is so remarkable: it entails that certain behaviours would be scientifically inexplicable if they were ever to occur. "The shock of this", says Leslie Valiant in *Probably Approximately Correct*, "is still taking its time to permeate the community of the educated."

A development of Turing's work suggests that certain other behaviours would be inexplicable, not because they would be absolutely impossible, but because they would take more time than our 14 billion-year-old universe can accommodate. Such time constraints are particularly important to Valiant's own line of research.

Equipped with these tools for studying the limits of scientific explicability, Valiant approaches the question of whether "all the complexities of life, intelligence, and culture" are explicable. His contention is that the "unevadable key" to explaining these phenomena is the mathematics of law-governed interactions with a regular environment. He calls the procedures for engaging in such interactions "ecorithms".

Valiant founded the theory of ecorithms in 1984. That theory has yielded several powerful results. If, for example, an environment contains items of various types, then it can be proved that there are ecorithms guaranteed to learn a system for classifying items into those types, given certain constraints on the criteria by which type-membership is decided. This is not a guarantee of unfailing performance. Those classificatory systems that can be learned in a feasible amount of time are only "probably approximately correct", but so are we. The argument is that, insofar as having a mind is a matter of learning how to classify things, our minds are indeed explicable.

One might doubt whether the other complexities of intelligent life lend themselves so readily to mathematical treatment. Valiant believes all such complexities to be explicable, and makes preliminary suggestions as to how their explanations might proceed, but he is also concerned to show how much explanatory work remains to be done, especially when considering the complexities of life.

The Origin of Species specified a mechanism by which the complexities of life might be explained. Valiant argues that this theory needs supplementing with a quantitative account of the way in which natural selection can get to solutions that have the complexity shown by nature, while operating in the available time. Saying only that natural selection explains the complexity of life is, for Valiant, like saying only that gravity and linear motion explain the planetary orbits. Newton needed to invent the calculus before a quantitative explanation of the orbits could be given. According to Valiant, Darwin's claims need an analogous mathematical apparatus, one that can be built by taking natural selection to instantiate an ecorithm for Probably Approximately Correct learning.

Valiant explains enough of this apparatus for the promise and difficulty of his suggestion to be clear. Mathematically averse readers will find some passages heavy-going, but few to be impossible. The use of formulae is kept to a minimum, and is accompanied by informal clarifications.

Valiant extracts several philosophical lessons from the ideas that he presents. Some of these take the form of homely advice. Systems that learn by Probably Approximately Correct methods are unavoidably vulnerable to prejudice. Humility is counselled. Valiant also advises against taking philosophical thought experiments too seriously. Concepts like "consciousness" must, he thinks, be vague, and the questions raised in philosophers' thought experiments may have no determinate answer. Valiant's argument on this point is rather too quick. The lack of a theory within which "consciousness" is defined need not entail that that concept is a vague one. The concept might instead get a precise meaning from our acquaintance with consciousness itself, in our own experience.

Such qualms do little to compromise the importance of Leslie Valiant's research to our understanding of intelligent life. This book makes some of that research accessible to a broad audience.

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