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Ken Steiglitz, *The Discrete Charm of the Machine: Why the World Became Digital*, Princeton University Press, 2019, 235pp., £22, ISBN 978-0-691-17943-8

What do the Grand Vizier Sissa Ben Dahir's grains of rice on a chessboard, the 'bible per square inch' unit of measurement, and Mozart-loving aliens all have in common? They're all illustrative analogies used in Ken Steiglitz's engaging and explanatory book exploring the reasons behind the triumph of discrete, digital computation over continuous, analogue systems.

In a sense, the key word to note in the title is 'Why': this book covers *technical* reasons for this wholesale shift in representation and calculation, largely effective in the 20th Century, without going too deeply into the 'how'. Steiglitz writes for a reader interested in science but with no technical training—there is some mathematics, some computer science, and most of all some physics, but by and large this is not overly taxing. This is not, however, an academic book for trained historians either: while there is some sketching of historical events and actors there is little explanation of context and motivation beyond technical advancement.

Four major themes run throughout the book, and if the reader is interested in understanding any of these at a conceptual level, they should find the book useful. The themes are: 1) physical laws put very definite limits in place on computing and communication hardware; 2) the 'noisy' (in the technical sense) world always causes problems for communication; 3) digitising signals makes them easier to process for cleaning and optimisation; 4) discretisation also allows better abstract understanding of computation.

The book's first part, 'A Century of Valves', discusses the shift from analogue to digital devices in all kinds of electronics and consumer goods, before considering the advantages to signal clarity brought by digital standardisation and diving into the physics behind electronics. The section wraps up by looking at the techniques used to create modern silicon hardware and physical limits to the miniaturisation enjoyed so far.

Part II, 'Sound and Pictures', looks at the conversion of data from the analogue world into the digital form needed for computation, and the principles of sampling. The second chapter in this part takes similar ideas and applies them to communication, highlighting how Shannon in particular made contributions to information theory.

The third and longest part of the book, 'Computation', starts back in the analogue world and has a brief chronological sketch of some analogue computing machines throughout history. The usual suspects like the Antikythera mechanism and Babbage's engines appear alongside less well-known examples such as the watery 'Financephalograph'. Next, the ingredients of computation (as the author sees them) are laid out alongside his view on their provenance, before being brought together in a description of the Turing Machine. The part moves then into theoretical computer science with an extended look at complexity theory and a consideration of whether analogue machines (unlikely) or quantum computers (possibly) could prove better than classical digital machines at solving certain problems. Finally and in the most diverse chapter, there is a consideration of the encoding of consciousness itself.

The book concludes with Part IV, entitled 'Today and Tomorrow', which overviews the technologies of the Internet and AI. Steiglitz wraps up with an exhortation to teach robots love and creativity—and concludes with those aforementioned aliens.

Overall, the book is an interesting romp through quite a variety of ideas, and it is to the author's credit that he manages to make them all tie together—even as the scope broadens exponentially towards the end. The knowledgeable historian will not learn much about the history of computing—the historical material is somewhat Whiggish in tone and lacking in critical analysis while sketches of historical actors are somewhat rudimentary and at times even hagiographic (Feynman, in particular, features very heavily). However Steiglitz does clearly know history, and there are quite extensive footnotes pointing to more lengthy historical works. There are some very nice examples of scientific progress being driven by curious puzzles, but few if any non-technical reasons given for advances.

The physicist, engineer, and mathematician are unlikely to learn new things about *their* particular fields; but where the book shines is in its bringing together of concepts from these areas and explaining them in terms which are usually easy to follow. To the entirely non-technical reader some of the physics, particularly quantum, gets a bit rough (the mathematics and computing involved is fairly elementary). At times it's not totally clear that such depth is necessary, but the author often succeeds in turning away just as the concepts become too tricky and providing instead a sketch or simile. Chapter 6's analogy of an LED on the side of a wheel, for example, does a great job in illustrating the principles of waveform sampling (and providing a by-the-way explanation of the curious phenomenon in which slowing vehicle wheels on film seem to reverse direction).

The book is at its weakest when providing only shallow overviews of rather complicated fields, as in the final chapter, where the light touch unfortunately misses anything particularly solid. It is at its best when telling charmingly personal anecdotes (these are peppered throughout and always provide a nice, if nostalgic, humanising factor); and when bringing out nice illustrations of phenomena. See, for example, the Grand Vizier who appears in Chapter 5 with his demonstration of the power of exponentiation.

The narrative is mostly European and USA-centric—Grand Vizier notwithstanding—and so it is somewhat surprising how US-biased the view of theoretical computing is. A whole chapter is devoted to the topic of complexity theory, a notion of which is described as "the key to the most important idea in computer science" (p. 159), which seems odd given that in Europe there is very little focus on complexity in a thriving theoretical computing community.[1]

One final slight niggle: throughout the book Steiglitz teases the notion that analogue computing machines might be capable of doing things that digital ones cannot. When this topic is directly addressed in Chapter 11, however, he is quite emphatic that this seems very unlikely. It is an odd sticking point in an otherwise very coherent book.

In summary: *The Discrete Charm of the Machine* packs a lot of ideas into a rather slim and very readable work, nicely explaining most of the technical points that are involved in digital computing at a hardware level. There is a lack of detail in some places and too much in others, but overall the interested reader will find a lot to like here (and in the broad variety of suggested further reading)—as long as they do not mistake it for a history book!

Troy Astarte,

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[1] . But perhaps that stood out to the reviewer only because the history of European computer science is their particular field!

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