

Celebrating Claude Shannon's Legacy

A Mind at Play: How Claude Shannon Invented the Information Age. By Jimmy Soni and Rob Goodman. Simon and Schuster, New York, NY, July 2017. 384 pages. \$27.00.

Jimmy Soni and Rob Goodman's claim that mathematician Claude Shannon (1916-2001) "invented the information age" seems like an overstatement, but only a slight one.

Shannon's 1948 treatise, "A Mathematical Theory of Communication," was an extraordinary work of genius that laid the foundations of information theory. It set up the basic conceptual framework for analyzing information and communication across a noisy channel; defined central concepts, particularly entropy; and proved the fundamental bounds on efficiently coding information and communicating it across a noisy channel. The paper was spectacularly clear and extremely readable, with an entertaining extended digression on the use of k-gram Markov models to generate language-like text. While Shannon did not arrive entirely at the theory out of the blue—he cited earlier work by Harry Nyquist and Ralph Hartley, and concurrent work by Norbert Wiener, among others—the credit for most of the content and the elegant conceptual package belongs purely to him.

Shannon's other great accomplishment was his 1937 master's thesis, "A Symbolic Analysis of Relay and Switching Circuits," which largely invented the analysis of digital circuits in terms of Boolean algebra; Shannon proved that any Boolean function can be computed using switching circuits. He also contributed to foundational work in computational linguistics, cryptography, and artificial intelligence.

Shannon's scientific genius was combined with an extraordinarily easy temperament. He was uninterested in fame and had little interest in fortune, though in fact he was quite well off due to, successful, early investments in technology companies. His passions were for his scientific work, for tinkering with ingenious physical devices, for chess, for jazz, for juggling, and for unicycling — for whatever caught his interest, either serious or playful. He was altogether unpretentious, with a quiet, understated, self-deprecating wit and no taste at all for pompous pontification.

Shannon had a remarkably realistic view of his own work. After the publication of "A Mathematical Theory of Communication"—when information theory became all the rage and was hyped by both scientists and the popular press, often

with more excitement than understanding—he felt obliged to write a short essay, "The Bandwagon," to caution against unrealistic expectations:

While we feel that information theory is indeed a valuable tool in providing fundamental insights into the nature of communication problems and will continue to grow in importance, it is certainly no panacea for the communication engineer or, *a fortiori*, for anyone else. Seldom do more than a few of nature's secrets give way at one time. It will be all too easy for our somewhat artificial prosperity to collapse overnight when it is realized that the use of a few exciting words like *information*, *entropy*, *redundancy*, do not solve all our problems.

On the whole, Shannon enjoyed a pleasant, quiet, and satisfying life, though a few clouds do appear in his biography. His father died when he was young and he quarreled with his mother. He did not much enjoy the year he spent at the Institute for Advanced Study, and seems to have disliked his cryptanalysis work for World War II, though he never talked much about it. Although Shannon's first marriage ended after a year, a thoroughly happy second marriage lasted until the end of his life. Joseph Doob wrote a harsh, unfair review of "A Mathematical Theory of Communication."

Norbert Wiener created a small fuss about the comparative merits of his own theory of cybernetics vis-à-vis Shannon's information theory — a fuss that upset the neurotic Wiener much more than the placid Shannon. Tragically, Shannon succumbed to Alzheimer's in his last years.

But for most of his life he lived at peace with the world, happy in his marriage, enormously admired by his colleagues and the world at large, and employed at jobs—first at Bell Labs and then at the Massachusetts Institute of Technology—that almost entirely allowed him to live as he liked and do precisely what he wanted.

Shannon epitomized the stereotype of the genius as eccentric; no one could have been further from the stereotype of the genius as a tortured soul.

Shannon was universally lauded and admired; he was showered with prizes, honors, and so many honorary degrees that he built a device resembling a rotating tie rack to hold all of the hoods. Even Doob eventually came around. In 1963, Andrey Kolmogorov wrote that "[Shannon] can be considered equally well as one of the greatest mathematicians and as one of the greatest engineers of the last few decades."

A Mind at Play: How Claude Shannon Invented the Information Age is the first full-length biography of this great scientist, and it is excellent. It is superbly written, easily readable, and thoroughly researched.

Though the authors do not come from a scientific background—their previous collaboration was a biography¹ of Cato the Younger, the opponent of Julius Caesar—as far as I can tell, they get everything right. The exposition of the science is crystal clear and correct,² though not at all deep, even by popular science standards. The character portraits and evocations of the historical atmosphere possess the ring of truth, and historical judgments are sound and fair. Soni and Goodman explain the impact and significance of Shannon's work very clearly and in depth, but—like Shannon himself and unlike many biographers—they do not overhype it.

The authors recount all well-known anecdotes of Shannon, including the whimsical devices he built: his mechanical mouse "Theseus," which learned a maze; his THROBAC machine, which computed in

Roman numerals; the "Ultimate Machine," which turned itself off when turned on; flame-throwing trumpets; and juggling machines. They have also unearthed some lesser-known projects: Shannon's collaboration with Edward Thorp, wisely abandoned, to build a wearable computer that would beat the odds on roulette wheels; a chess-playing computer he built in 1949, which played the end game with six pieces; an unpublished 70-line poem entitled "A Rubric on Rubik's Cube," to be sung to the tune of "Ta-Ra-Ra Boom-De-Ay!"

Soni and Goodman also tell the curious story of Shannon's doctoral thesis, which—for good reasons—is comparatively obscure. In 1910, during the flush of the eugenics movement, the Eugenics Record Office (ERO) was established in Cold Spring Harbor, NY, with funding from the Carnegie Institution and other sources. 25 years later, the eugenics movement had been discredited. Vannevar Bush, who was then president of the Carnegie Institution, decided to withdraw its funding, and the office closed in 1939. Meanwhile, the ERO had accumulated an enormous quantity of genealogical and personal information, some of it meaningful. Bush sent Shannon there to work with geneticist Barbara Stoddard Burks and sift through the material for any valuable information. Shannon's thesis developed an algebra for theoretical genetics. It was mathematically creative, but reflected major gaps in his command of the literature; he reproved a theorem that had been known for two decades. The work was not published and Shannon did not pursue the subject any further. However, according to a current expert in population genetics, whom Soni and Goodman consulted, there would have been some value in its publication, in hindsight.

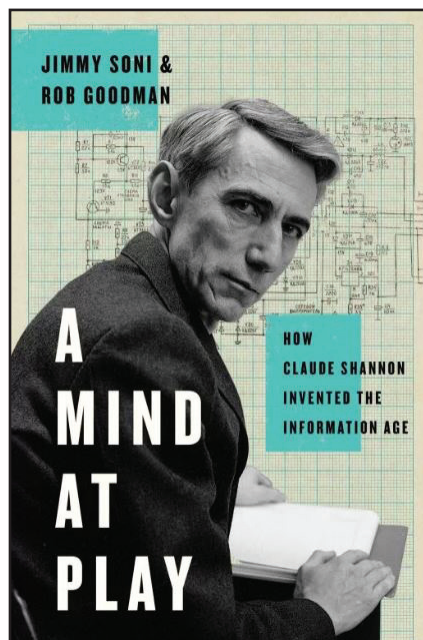
Since Shannon's life was not enormously eventful, the book has plenty of room for background and supplementary material, including short biographical sketches of Nyquist, Hartley, Doob, Wiener, Bush, Burks, and Warren Weaver; and historical accounts of various analog computers, such as Lord Kelvin's tide-predicting machine.

All in all, *A Mind at Play* is a very entertaining and important account of the life and works of an extraordinary scientist.

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BOOK REVIEW

By Ernest Davis



A Mind at Play: How Claude Shannon Invented the Information Age. By Jimmy Soni and Rob Goodman. Courtesy of Simon and Schuster.

¹ *Rome's Last Citizen: The Life and Legacy of Cato, Mortal Enemy of Caesar* (2012).

² I spotted one tiny error, too minor to be worth describing.