Brainstorm

How NEURAL NETWORKING's pioneers survived defections to AI and brought applications into use. BY MARK WILLIAMS

Talking Nets: An Oral History of Neural Networks
Edited by James A. Anderson and Edward Rosenfeld
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MOST OF the 17 neural network scientists interviewed in *Talking Nets: An Oral History of Neural Networks* at some point ponder the eclipse their field suffered between 1965 and 1985. Robert Hecht-Nielsen, a cofounder of HNC Software, summarizes the charge against the man held most responsible for diverting funding away from neural networks and toward artificial intelligence (AI): "[Marvin] Minsky's early career was like that of Darth Vader. He started out as one of the earliest pioneers in neural networks, but was then turned to the dark side of the force [AI] and became the strongest and most effective foe of his original community." Mr. Hecht-Nielsen adds, "Invited to give the keynote address at a large neural network conference in the late 1980s to an absolutely rapt audience, [Minsky] began with the words: 'I am not the Devil!'"

Neural networks represent the thrust to discover our brains' mechanisms and reproduce them within computer systems, whereas AI aims to synthesize machine minds without resorting to models derived from biological nervous systems. Though the grand ambitions of AI proponents like Mr. Minsky have produced nothing after three decades, neural networking has now advanced to the point where substantive applications are moving into practical use.

Talking Nets casts the field's history thus far in the voices of those who struggled to build careers in and find funding for neural networking. These are idiosyncratic thinkers who, believing that no scientific problems were as important as those posed by the nascent field, persisted through every professional frustration.

THE TURING POINT

From the beginning, research into neural networks accompanied electronic computing's development. Norbert Wiener, cybernetics' originator, and John von Neumann were involved in both. Von Neumann's architecture remains the basis for almost all of today's computers. The Hungarian-born polymath believed that the mechanisms behind biological networks relied on parallel processing, rather than something analogous to the serial processing of digital computers: his writings considered how, though computers with 10,000 parts failed, the human brain, with 10 billion unreliable neurons, functioned dependably. In *Talking Nets* Michael Arbib repeats a story that the neural modeling pioneer Warren McCulloch liked to tell, of how von Neumann called one night saying, "Warren, I've drunk a whole bottle of absinthe. I know the thresholds of all my neurons are shot to hell. How is it I can still think?"

Walter Freeman reckons McCulloch "the godfather of the digital computer since von Neumann relied upon him so heavily for his neural metaphors." In 1943 McCulloch and Walter Pitts proposed a binary, on-off model of neurons and examined the nervous system as a Turing Machine. *Herring* readers know that the computer age's most important source document is Alan Turing's proof of a "universal machine" that, with the correct written instructions, computes anything computable: the British mathematician hypothesized a machine that either makes or erases a mark on a finite but unbounded length of tape, then moves that tape one square to the right or left; more complicated tasks don't require more complicated Turing machines, only more complicated instructions. McCulloch and Pitts, treating the brain in this light, showed that nervous activity was deconstructable into elementary components.

Pitts was the more remarkable of the two men. According to interviewee Jerome Lettvin, Pitts discovered Bertrand Russell's and Alfred North Whitehead's *Principia Mathematica* as a 12-year-old Chicago newsboy hiding from street toughs in a library's back stacks. He spent three days there reading the *Principia*, then wrote to Russell explaining its flaws and began attending the University of Chicago without

registering. Mr. Lettvin met him at a Russell lecture and later related Pitts's story to Wiener, who declared, "There doesn't exist such a person." Mr. Lettvin and McCulloch then bought Pitts a railroad ticket to Boston; Pitts stayed at Harvard to work with Wiener.

THE DOORS OF PERCEPTRONS

Between 1965 and 1985, the field teetered on the brink of extinction, triggered by the success of Mr. Minsky and Seymour Papert's AI book, *Perceptrons*. Perceptrons were simple learning networks in which a pattern associator was fed series of inputs and also correct outputs: the perceptron adjusted itself until outputs matched inputs. But single-layer perceptrons couldn't compute "exclusive-or" operations—"implement A or B, but not both." Mr. Minsky and Mr. Papert collected similar examples of single-layer perceptrons' failings and also lectured at conferences. For two decades, funding for neural nets dried up as organizations redirected money toward research promoted by Mr. Minsky's AI camp.

By the mid-'80s, however, new thinkers began asserting themselves. The Parallel Distributed Processing (PDP) Group, emerging in California, emphasized "connectionism," the brain's massively parallel architecture. The group's David Rumelhart promulgated "backpropagation," an idea Paul Werbos had developed in the early '70s. He saw backpropagation as a solution to the perceptron's problems—where layers of hidden units interpose between inputs and outputs, the output units will propagate back to *each* hidden unit a signal representing the sum of the hidden unit's errors across *all* the output units that it is connected to.

The PDP Group's ideas were widely circulated. Also, Mr. Hecht-Nielsen and Bart Kosko appeared on the scene, advocating neural networks with the same political insistence the AI camp had displayed. Today, we're just beginning to witness the eruption of intelligent neural networking agents and applications into everyday life.

What's ahead? Asked to speculate, almost all of *Talking Nets*' subjects discuss their desire for a working theory of consciousness. Leon Cooper, for example, explains, "I'm really a no nonsense physicist. I just want to have a little machine...that becomes conscious." Others are more cautious. Mr. Hecht-Nielsen, a businessman, speculates that it may take three centuries before the brain is understood.

Nevertheless, he adds, "[T]he efforts that many of us have put in are coming to something. This is not a flash in the pan. It's not something that becomes a small part of something larger. This *is* that large thing."

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