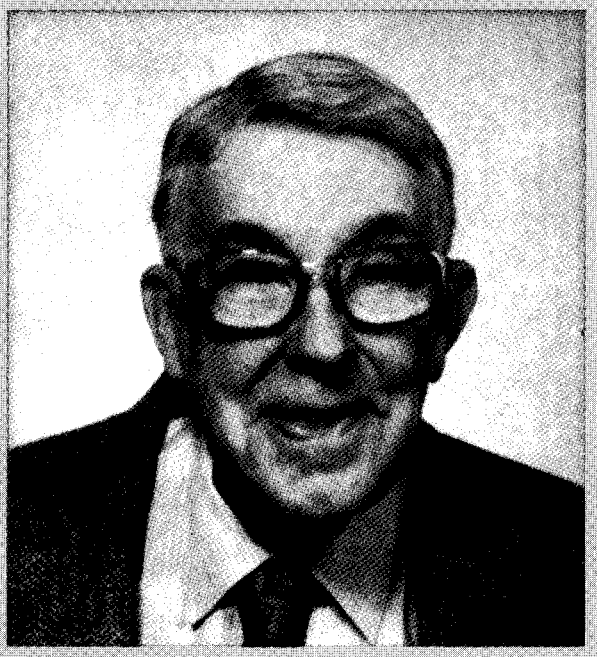
Arthur Samuel: Pioneer in Machine Learning



Professor Emeritus Arthur L. Samuel died July 29, 1990, in Stanford, California at the age of 89. He was a pioneer of artificial intelligence research whose life spanned a broad personal and scientific history.

Arthur Samuel was born in Emporia, Kansas in 1901. He graduated from M.I.T. with a Master of Science degree in electrical engineering in 1926, and worked intermittently for the General Electric Company in Schenectady, New York. He later did graduate work in physics at Columbia University. His undergraduate school, the College of Emporia, awarded him an honorary doctorate in 1946.

After receiving his Master's degree, Samuel stayed on at M.I.T. as an instructor in electrical engineering until 1928, when he joined Bell Laboratories. At Bell Labs he worked primarily in electron tube research. Particularly notable was his work on the space charge between parallel electrodes and his wartime work on the TR-box (a switch that disconnects the receiver of a radar when the radar is transmitting to prevent the sensitive receiver from being destroyed by the high-power transmitter).

In 1946 Samuel became Professor of Electrical Engineering at the University of Illinois and became active in the University's project to design one of the first electronic computers. It was there that he conceived the idea of a checkers-playing program that would beat the world champion and demonstrate the power of electronic computers.

From 1947 to 1949 he served as an expert consultant to the U.S. Department of Defense and was chairman of the Advisory Group on Electron Tubes. He received the Exceptionally Meritorious Civilian Service Award from the D.O.D.

In 1949 Samuel joined the IBM Poughkeepsie Laboratory; this move was seen by IBM's competitors as a commitment by IBM to vacuum-tube-based computing, since he was a known expert in electron tube design. But as his autobiography describes it, he had a dual role there: pushing research on switching transistors and keeping engineers going with the available tube technology. Tubes were used for logic and memory in the first IBM stored-program computer, the 701. The memory was based on Williams tubes, which stored bits as charged spots on the screen of a cathode ray tube. Samuel managed to increase the number of bits stored from the customary 512 to 2048 and to raise the mean time to failure to half an hour. Memory capacities of those machines eventually grew to 8K words.

For several years in the early 1950s, Samuel was the manager of the laboratory that was the precursor of the IBM Research Division. He completed the first checkers-playing program on the 701, and when it was about to be demonstrated, Thomas J. Watson, Sr., the founder and President of IBM, remarked that the demonstration would raise the price of IBM stock 15 points. It did.

The Samuel checkers-playing program appears to be the world's first self-learning program, and as such, a very early demonstration of a fundamental concept of artificial intelligence (AI). Programs for playing games fill the role in AI research that the fruit fly (Drosophila) plays in genetics. Drosophilae are

convenient for genetics because they breed rapidly and are cheap to keep, and games are convenient for AI because it is easy to compare computer performance with that of people.

Samuel took advantage of another fact about checkers for his learning research: Checkers players have access to many volumes of annotated games, with the good moves distinguished from the bad ones. Samuel's learning program replayed the games presented in *Lee's Guide to Checkers* to adjust its criteria for choosing moves so that the program would choose those thought good by checkers experts as often as possible.

In 1961, when Edward Feigenbaum and Julian Feldman were putting together the first AI anthology, *Computers and Thought*, they asked Samuel to give them, as an appendix to his splendid paper on the checkers player, the best game the program had ever played. Samuel used that request as an opportunity to challenge R. W. Nealy, the Connecticut state checkers champion and the fourth-ranked player in the nation. Samuel's program won. Nealy provided annotation and commentary on the game when it was included in the volume.

In that year, 1962, the early programs still had some fairly serious defects because of the linearity of the evaluation polynomial. Samuel persevered in a long series of experiments and program modifications. Five years later he published the second machine-learning paper, describing some radical improvements and newly developed techniques, including his famous signature-table algorithm for combining parameters nonlinearly.

Because his checkers work was one of the earliest examples of non-numerical computation, Samuel greatly influenced the instruction set of early IBM computers. The logical instructions of these computers were put in at his instigation and were quickly adopted by all computer designers, because they are useful for most non-numerical computation.

Samuel was a modest man, and the importance of his work was widely recognized only after his retirement from IBM in 1966. He did not relish the politics that would have been required to get his research more vigorously extended. He was also realistic about the large difference between what had been accomplished in understanding intellectual mechanisms and what will be required to reach human-level intelligence.

Samuel's papers on machine learning are still worth studying. With great creativity and working essentially alone, doing his own programming he invented several seminal techniques in rote learning and generalization learning, using such underlying techniques as mutable evaluation functions, "hill climbing," and signature tables. There have been more than 100 literature citations of his two *Journal* papers, some of his innovative programming techniques have been applied in fields of research other than artificial intelligence, and one still hears proposals for research within artificial intelligence that are less sophisticated than his work in the 1950s.

Besides engineering and computer science, Samuel did important management work at IBM. He played a large role in establishing the IBM European laboratories and setting their research directions, especially in Vienna and Zurich. He also served as editor of the *IBM Journal of Research and Development* during an early period of its growth as an influential primary journal.

On his retirement from IBM, Samuel came to Stanford University as a Lecturer and Research Associate, starting yet another new career. In 1974 he became a research professor at Stanford, where he continued his work on checkers until his program finally became outdated in the late 1970s. He also worked on speech recognition until the funding agency, DARPA, decided to concentrate its speech work on developing one single approach. He taught actively until 1982, and supervised several Ph.D. theses at Stanford.

Samuel remained an active computer programmer long after age forced him to give up active research. His contributions included work on the SAIL operating system, on software for the Livermore S-1

multiprocessor, and on the TEX typesetting system. His last work, continued up to the age of 86, involved modifying programs for printing in multiple type fonts on some of the Stanford Computer Science Department's computers. We believe he was the world's oldest active computer programmer. The Stanford computer he used tells us that he last logged on to it on February 2, 1990; his home computer was still used throughout the summer.

One of Samuel's talents was understanding inadequate documentation of complicated programs and writing clear and attractive manuals. His "First Grade Tex" was recently translated into Japanese. He also started an autobiography, which, unfortunately, takes us only to the middle 1960s.

Arthur Samuel was a Fellow of the Institute of Electrical and Electronics Engineers, the American Physical Society, the Institute of Radio Engineers, and the American Institute of Electrical Engineers, and a member of the Association for Computing Machinery and the American Association for the Advancement of Science.

As a person, he was distinguished by his objectivity and his kindness in helping many people, especially in learning about the many matters in which he was expert.

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