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REMEMBERING Herbert A. Simon, *Wizard of the Artificial Sciences*

June 15, 1916–February 9, 2001

by Andrew Vazsonyi, Feature Editor

Herbert A. Simon, founder of the artificial sciences and the Richard King Mellon University Professor of Computer Science and Psychology at Carnegie Mellon University, died on February 9, 2001. He was 84 years old.

Many of us in the decision sciences owe a tremendous debt to Simon and his groundbreaking work. I can hardly begin to acknowledge the contributions he made to my professional life. His publications influenced my outlook and philosophy on the decision sciences more than anything else. In my nearly completed memoirs, I write about Herb as follows.

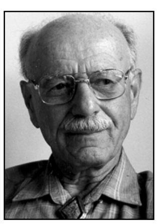
I first met Herb Simon while relaxing on a Santa Monica beach in 1950. He was a professor of psychology at the Carnegie Institute of Technology doing research in administrative behavior. During a long conversation about his consulting work for the RAND Corporation—he was checking into forecasting theories for a paint factory—he surprised me by taking a radically different attack from the standard linear programming approach. Instead of optimizing, he assumed that the factory wanted to get an acceptable solution. However, the objective function was nonlinear, V-shaped, causing him a lot of trouble.

Based on my experiences in 1946 while working on a control mechanism for one of the first U.S. supersonic missiles, I suggested that he try using orthogonal Legendre polynomials. It turned out that my idea was a bum steer—a mathematician's approach to the problem. Nonetheless, he seemed intrigued by its novelty.

Simon was no mathematician, though he was definitely well-versed in math. (He admitted that in school he only got as far as calculus, but later on he applied himself to learning math by diligent work. His efforts paid off, because in *Models of Man* he used algebra and calculus as his principal language.) I greatly enjoyed our friendly debate and walked away feeling very impressed by him. Little did I suspect that this chance meeting would lead to us becoming life-long friends—his last e-mail to me was dated August 21, 2000.

In 1953, when a few of us founded The Institute of Management Sciences, Simon was very supportive of our efforts and added his name to the list of signatories on the organization's announcement that I wrote in August of that year. He was active in our activities to the end of his life by giving talks at our meetings and writing papers for our journals.

Five years later, when I came across Simon's book *Models of Man, Social and Rational, Mathematical Essays on Rational Human Behavior in a Social Setting* (John Wiley, 1957), it dawned on me what he was up to. While I was modeling the control of missiles by servo theory, based on differential equations, he was modeling humans. He tried to set forth a consistent body of theory of the rational and non-rational aspects of human behavior in a social setting. Most of his essays used mathematical models for utilitarian rather than aesthetic grounds. His primary purpose was to bring the same rigorous methodology to the social sciences that existed in physics and other hard sciences. The secondary purpose of the essays were to provide material in the application of mathematics in social sciences to the typical researcher, who in general wasn't well-versed in math.



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Models of man was like a wake-up call for me as a mathematician who was trying to apply math to the real world. Unfortunately, it is out of print and largely forgotten – unlike Simon's earlier book *Administrative Behavior, a Study of Decision-Making Processes in Administrative Organization* (The Free Press, 1945), which was hailed as one of the greatest contributions to 20th century business management. It went through four editions — the final edition was published in 1997. By the way, there is no math in this book—the modeling is in ordinary prose.

This book challenges the theory that humans behave rationally, and that decisions are made with a view to securing the optimum result. Simon rejected the notion of an omniscient economic man capable of making decisions from his Olympian heights that bring the greatest benefit to all. He proposed that humans look for a course of action that is satisfactory, good enough, reasonable, or acceptable. In today's complex world, not even the most powerful computers can process all the information, even if they could obtain it, that humans need to make fully rational decisions. Quite simply, Simon expressed the view that humans don't have the wits to optimize. He called this less ambitious view of human decision making "bounded rationality," or "intended rational behavior" and "satisficing."

In *The New Science of Management* (Prentice Hall, 1960) he examined how computers had influenced, and would continue to do so, the processes of management, and especially management decision making. To understand the nature and import of these changes, he viewed them in the context of the mechanization and automation of work and the workplace, and of the continuing advance of technology. He was concerned with the wider social effects of computers as well as their immediate consequence for the processes of making decisions. His discussion of the three decision phases that most executives follow has served me as a life-long guide:

- The first phase of the decision-making process—searching the environment for conditions calling for a decision—is the *intelligence* activity (borrowing the military meaning of intelligence).
- The second phase—inventing, developing, and analyzing possible courses of action—is the *design* activity.
- The third phase—selecting a particular course of action from those available—is the *choice* activity.
- (He also mentioned a fourth phase—assessing past choices, the *review* activity—but most of his attention was focused on the first three.)

An essential feature of satisficing analysis is embodied in the Subjective Expected Utility (SEU) Theory. This theory orders the desirability of each choice the decision maker is considering by assigning a subjective value, an index, a measure to the choice. The algebraic way to state the SEU to a choice with four possible outcomes is:

$$\text{Subjective Expected Utility} = \text{SEU} = p_1 u_1 + p_2 u_2 + p_3 u_3 + p_4 u_4,$$

where p and u are the respective subjective probabilities and personal utilities of each outcome. Thus the SEU is the long run, weighted mean of utilities, where the weights are the probabilities. When the decision maker is comparing two choices, the one with the higher SEU is to be selected.

The development of SEU theory was a major intellectual achievement of the first half of this century. For the first time it supplied a formal statement of what it would mean for a decision maker to behave in a consistent, rational manner. By admitting subjectively assigned probabilities, SEU theory opened the way to fusing subjective opinions with objective data, an approach that can also be used in man-machine, decision-making systems. The assumptions of SEU theory are very strong, permitting correspondingly strong inferences to be made from them. Although the assumptions cannot be satisfied even remotely for most complex situations in the real world, they may be satisfied approximately in some problem situations that can be isolated from the world's complexity and dealt with independently.

Most of the methods of modern decision making use the SEU theory. They assume that what is desired is the achievement of some goal under specified constraints and assuming that all alternatives and consequences (or their probability distributions) are known. These tools have proven their usefulness in a wide variety of applications, and heuristic search techniques are available to improve solutions. In certain situations, search algorithms have been found to maximize SEU and thus optimal solutions have been obtained.

The Sciences of the Artificial

Simon's 1969 book, *The Sciences of the Artificial* (MIT Press), had a huge impact on me. It took Simon's genius to articulate that *natural* history—the sciences, physics, biology, chemistry—deal with the *natural* events of the world. For instance, Kepler's three laws control the motion of the planets and allow scientists to predict the future position of the planets. But humans also live in another kind of environment that Simon dubbed the *artificial.* When he said that the objects of math are not only *natural* but also *artificial*, he provided a sturdy framework to fit all things related to decision making.

According to Simon, *cognitive science* deals with the common concerns shared by the disciplines of artificial intelligence, cognitive psychology, business management, computer science, economics, linguistics, epistemology, operations research, management science (most important for us), philosophy, public administration, and the social sciences in general. He also redefined cognitive science as "the domain of inquiry that seeks to understand

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SIMON WAS WELL KNOWN FOR HIS LOVE OF DEBATE regardless of the subject or the setting. Former colleagues at Carnegie Mellon like to tell of Simon's habit of coming into the cafeteria, choosing a table at random, sitting down, and saying, "Tell me about your research." After listening for a few minutes, he would then announce: "Unfortunately, you're wrong." Then he would hold forth on the subject just to see how long he could maintain his position.

intelligent systems and the nature of intelligence." Here intelligent systems include natural (biological) and artificial (computer-based) systems. They include the theory and practice of decision making, and such action-oriented goals as improvement of education and training of humans.

The Father of "Artificial Intelligence"

Although Simon is considered the father of "artificial intelligence," he never cared for that particular expression and didn't use it in his book *Scientific Discovery* (The MIT Press, 1987, jointly with P. Langly, G.L. Bradshaw, and J.M Zytcow), where he discussed the BACON computer programs. These programs are the most illuminating proof, as far as I am concerned, that computers can compete with the best human minds in reasoning processes.

Simon developed his theory of scientific discovery by the hypothesis that the mechanism of scientific discovery is a special case of the general process of problem solving. He examined a number of celebrated laws of nature, dug into the historical records to find the data available to researcher of the time, and studied the problem how to get the laws (that is, the formulas) from the data.

For example, he fed the data known to Johannes Kepler to BACON, which produced as its output the three laws discovered by Kepler. Consider, as an illustration, Kepler's third law. It establishes a functional relationship between

D — Average distance from the sun

P — Time to complete one revolution around the sun, the period of the planet

Kepler discovered the functional relationship: D3/P2 = constant.

So did the BACON program.

Many other great scientific discoveries have been made solving problems of this sort. For example: Boyle's discovery of the law relating the pressure of a gas to its volume, Galileo's discovery of the law of uniform acceleration, Ohm's discovery of the law of electric conductivity, and Newtons's discovery of the law of universal gravitation. In each of these cases the data was available, but not the law. In each case BACON found the law. How BACON became a super genius becomes clear to any mathematician who takes the time to study the principles underlying the programs.

Once somebody asked Simon if he could identify anyone as the Newton of cognitive science. He supposedly replied: "It would be immodest for me to say."

The Last Email

In one of his Herb's last e-mails he suggested— very tongue in cheek— that we write a joint paper so that his Erdös number (mine is one because I once co-wrote a paper with the great mathematician Paul Erdös) would be reduced from infinite to two, thus lessening a long-standing sorrow of his life. With his passing, Simon joins Erdös as one of my most important heroes, my *privy councilors.* He lives on in my thoughts, as well as in his publications and on my computer.When I'm stuck on a problem, I can still ask, "What would you advise me to do, Herb?" Then I can search for his work on the Internet, where I'll get a 100 or so hits. And I can browse through his assorted books and articles. Each time I do, I'm sure to find something new and exciting that will make our imaginary "debate" very enlightening. ■

From the 2/10/01 *New York Times* Orbituary

Herbert Simon died at the Presbyterian University Hospital of Pittsburgh, according to an announcement by Carnegie Mellon University, which said the cause was complications after surgery last month.

He was born in Milwaukee on June 15, 1916. The son of German immigrants, he attended public school and entered the University of Chicago in 1933 with the intention of bringing the same rigorous methodology to the social sciences as existed in physics and other "hard" sciences. After receiving his bachelor's degree in 1936, he became an assistant to Clarence E. Ridley of the International City Managers Association and then continued work on administrative techniques in the Bureau of Public Administration at the University of California at Berkeley. In 1942, he moved to the Illinois Institute of Technology. A year later he received his doctorate from the University of Chicago for a dissertation subsequently published in 1947 as "Administrative Behavior: A Study of Decision-Making Processes in Administrative Organizations."

Since 1949, he has served as member of the faculty of Carnegie Mellon University, and played important roles in the formation of several departments and schools including the Graduate School of Industrial Administration, the School of Computer Science and the College of Humanities and Social Sciences' psychology department.

His contributions have been recognized by the following awards: A. M. Turing Award for his work on computer science (1975); National Medal of Science (1986); American Psychological Association's award for outstanding lifetime contributions to psychology (1993); and the 1978 Nobel Prize for "his pioneering research into the decision-making process within economic organizations." In 1994 he became one of only fourteen foreign scientists ever to be inducted into the Chinese Academy of Sciences. In 1995 he received awards from the International Joint Conferences on Artificial Intelligence and the American Society of Public Administration.

His autobiography, "Models of My Life," was published in 1991. His best known books are "Models of Bounded Rationality" (1997), "Sciences of the Artificial"(1996), and "Administrative Behavior"(1997).

Dorothea Pye, whom he married in 1937, survives him along with three children, six grandchildren, three step-grandchildren; and five great-grandchildren.