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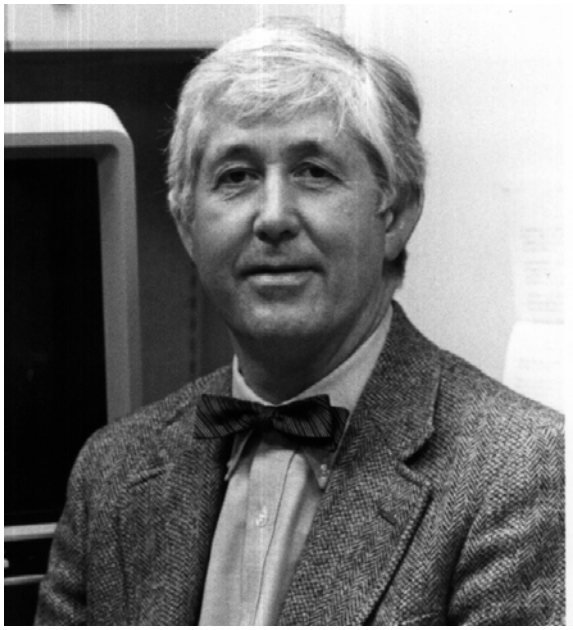
IN MEMORIAM: PETER D. WELCH (1928–2023)



Peter D. Welch was born in 1928 in Detroit, Michigan, and shortly thereafter his family settled in the suburbs east of Milwaukee, Wisconsin. The youngest of three siblings, with more than ten years separating him and his older brother and sister, Peter grew up with a good degree of independence. A self-described "child of the Great Depression," Peter also learned early on the value of hard work. His first job was delivering milk, and he subsequently worked paving roads, and attending at a gas station over summers spent with relatives in Wyoming. A job he particularly enjoyed was caddying at a local golf course, where he learned a game that he would play well past his eightieth birthday.

Peter started college at the University of Wisconsin–Milwaukee in 1946, and then in 1948, at the suggestion of a professor, he transferred to The University of Chicago. Although he never formally received a bachelor's degree, he nevertheless went on to earn two master's degrees, one in mathematics from the University of Wisconsin–Madison in 1951, and the second in physics from New Mexico State University in 1956. From 1951 to 1956, Peter worked at the Physical Science Laboratory of New Mexico State University, where among other pursuits he investigated how terrain variations affect signal processing by radar altimeters.

In 1956, Peter joined the IBM Thomas J. Watson Research Center in Yorktown Heights, New York, where he worked until his retirement in 1993. His initial work was on the use of signal processing techniques for speech recognition. In 1959 he joined a statistics and operations research group and did general statistical consulting including extensive work on IBM's passenger reservation system, Sabre, developed for American Airlines. His load smoothing algorithm became a permanent feature of the Sabre system. During this period, in 1963, he earned a Ph.D. in mathematical statistics at Columbia University; his thesis was on priority queuing systems.

From 1965 to 1973, Peter managed several projects within IBM Research involving signal processing and the use of the Fast Fourier Transform (FFT) with applications in seismic arrays, digital magnetic recording, data transmission, and x-ray image processing. In 1967, he published a fundamental article, Welch (1967), on a version of the FFT that yields smoother and more accurate estimates of the spectral density function while requiring substantially less computer time and memory compared with many other

publicly available versions of the FFT. The performance improvement is achieved by suitably combining the periodograms of shorter, but overlapping sections of a longer time series. Peter's version of the FFT is now widely known as Welch's Method; and the associated article, Welch (1967), has accumulated over 12,500 citations as reported by Google Scholar on July 31, 2023. Moreover, the article's citation count is increasing substantially each year because of the growing use of Welch's Method in Artificial Intelligence (AI) research and practice. The method is incorporated into MATLAB and the SciPy mathematical library, which is used in some machine learning systems. Based on the broad diversity of articles that cite Welch (1967), the impact of Welch's Method spans many scientific disciplines, including biology, medicine, physics, astronomy, geology, and computer science. For example, in diagnosing and monitoring the progression of Parkinson's disease, Yang et al. (2022) apply a leading-edge AI model to analyze big datasets obtained by using Welch's Method to compute the FFT of nocturnal breathing signals.

By around 1977, Peter became interested in problems arising in the analysis of discrete event simulations. This work was motivated by the development and widespread use within IBM of a computer performance modeling tool, the RESearch Queueing Package (RESQ), that was used by many designers to analyze the performance of future IBM computer systems. Working with Steve Lavenberg and Tom Moeller, he first focused on using control variates to reduce the variance of the simulation estimate of a selected mean response. In queueing networks, a large number of control variates such as sample service and interarrival times are possible. However, in Lavenberg, Moeller, and Welch (1982) the authors quantify a "loss factor" in variance reduction that is due to the estimation of the (unknown) vector of optimal control coefficients. This effectively limits the number of control variates that can be used in practice. Lavenberg and Welch (1981) is a state-of-the-art survey on the use of control variates in simulation, including the loss factor; and this paper won the 1982 Outstanding Simulation Publication Award from the College on Simulation and Gaming of The Institute of Management Sciences (now called the INFORMS Simulation Society or I-Sim).

When Phil Heidelberger joined IBM Research in 1978, Peter and Phil turned their attention to using spectral techniques for variance estimation in "steady state" simulations; the variance of the sample mean is asymptotic to the spectral density of the time series at 0 frequency, $p(0)$, divided by the sample size. This approach arose naturally from Peter's previous work on spectral analysis. They developed a regression-based technique for estimating $p(0)$ using low-order polynomials fit to the periodogram of the batch means arising from the time series (Heidelberger and Welch 1981). The traditional method of batch means assumes that the batch means are uncorrelated, thereby requiring a large batch size, whereas this method specifically estimates the correlation and can thus be used with smaller batch sizes. Meanwhile, Lee Schruben (UC Berkeley) proposed a technique for testing for stationarity using Brownian bridge statistics. This method also requires an estimate of $p(0)$, and Peter and Phil extended their technique to incorporating the estimated $p(0)$ into the Brownian bridge approach for estimating how much of the initial portion of the simulation, the "initial transient," should be discarded to ensure approximate stationarity of the remaining time series. Based on their technique for eliminating any initial transient, Peter and Phil developed a fully automated method of simulation run length control (Heidelberger and Welch 1983). This method was implemented in RESQ and could thus be used by practitioners without worrying about any of the details. The method is still in use; and Heidelberger and Welch (1983) has been referenced 1,698 times as of July 31, 2023, according to Google Scholar.

As part of their joint work, Peter and Phil looked at a large number of statistical plots. They began automating the generation of these plots, and this work led to the development of the software system GRAFSTAT (Burkland et al. 1984). GRAFSTAT, which preceded the widespread use of spreadsheets, was based on the APL programming language and became very widely used within IBM.

In addition to Peter's remarkable research contributions, Peter made extraordinary contributions in service to the international simulation community during the period 1983–2011. From 1983 to 1987, he served as the Simulation Area Editor for *Operations Research*; and in that capacity he established editorial standards for the publication of impactful simulation-related research that have been consistently maintained in *Operations Research* for the past forty years.

Perhaps Peter's most important service contribution was his role in the creation and ongoing maintenance of (i) the I-Sim website, http://www.informs-sim.org, which in 2011 was moved to https://connect.informs.org/simulation/home; and (ii) the Winter Simulation Conference (WSC) website, www.wintersim.org. In the spring of 1995, Dave Goldsman (Georgia Tech) was the president of I-Sim and the program chair of WSC 1995. In those roles, Dave recruited Peter to set up both websites. Peter continued to serve as the webmaster for I-Sim and WSC until his "retirement" in 2011.

As WSC webmaster, Peter worked closely with every WSC committee from 1996 to 2011 to carry out the timely posting of conference material, including the annual call for papers, the online author kit, and information on past and future WSCs. At the close of WSC 1999, the WSC Board of Directors approved a policy of making back volumes of the WSC *Proceedings* freely accessible on both the WSC and I-Sim websites. Then Peter undertook the formidable task of posting on the I-Sim website the entire contents of the WSC *Proceedings* from 1997 to 1999; and then he worked with each WSC committee from 2000 to 2011 to ensure that the latest WSC *Proceedings* appeared on the I-Sim website shortly after the close of each WSC.

During the period 1995–2011, Peter also established and continuously updated the email lists for both I-Sim and WSC. Since 1995 the WSC email list has grown to over 4,500 individuals, professional and governmental organizations, and vendors. These email lists have evolved into an essential tool for active, rapid communication with the international simulation community.

Peter's yeoman service as webmaster for both the I-Sim and WSC websites was critical to the rapid advancement of the status, visibility, and usefulness of both resources over the past three decades, especially as measured by the dramatic growth in the number of visits to both sites during that period. For example, in the mid-1990s, the WSC website received about 100 hits per month; and by the late-2000s, this figure had grown to about 1,300 hits per month.

Signal recognition of Peter's outstanding service to the international simulation community came in 2010 when he received the I-Sim Distinguished Service Award. Comprehensive recognition of all Peter's professional contributions over a career spanning six decades came in 2013 when he received the I-Sim Lifetime Professional Achievement Award; and a seventy-five minute interview with Peter was conducted and added to the Computer Simulation Archive at North Carolina State University. A common theme running through almost all conversations about Peter D. Welch is his engaging collegiality, wide-ranging curiosity, and legendary sense of humor. He will be greatly missed by his family, friends, and colleagues. He is survived by his wife, Carol; two children, Matthew and Rebeccah; and two grandchildren, Emma and Christina.

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