John von Neumann and the Origins of Scientific Computing [1]

Presented by

Joseph F. Grcar
Center for Computational Science and Engineering,
Lawrence Berkeley National Laboratory
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Reviewed by

John Michalakes
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In the real world, nothing happens at the right place at the right time. It is the job of historians to correct that. – Mark Twain

Poets are the unacknowledged legislators of the world. – Shelly

Joseph Grcar's "John von Neumann and the Origins of Scientific Computing" colloquium talk in the CU Applied Math series was a guilty pleasure. We entered the seminar room comfortably, knowing there would be no need for frantic note-taking or struggling to keep up with difficult material slide after cryptic slide. It was history, after all – where we've already been, not where we're going – and, most enjoyably, it was the CS, EE, and Applied Math audience's *own* history. We all love stories from our childhood, even those we've heard many times before. And here was a self-described "internalist historian": someone with a real job in the field who, by dint of their passion for the subject, had collected, classified, and teased out skeins of a bigger tapestry, then appeared before us to regale us with the tale of ourselves using wit, anecdote, curiosity, and poetry. There should have been popcorn.

Grcar's subject was the history of scientific computing and his themes were the evolution of and, at times, revolutions in the field – focusing on the role of "super-competent" individuals who at crucial moments changed "the paradigm." Beginning with Newton and proceeding through Mayer, Legendre, and Gauss, Grcar started from the seminal insight of scientific computing that predictive laws can be discovered but that observations never agree with predictions; then proceeded up through the history of fitting techniques – least squares and regression – whereby the discrepancies may be understood and themselves used for prediction; and finally to the current understanding that science is experiment, theory, *and* computation. Along the way, Grcar traces the history of the first "computers", human beings on the third floor of the US Coastal and

Geodetic Survey building in Washington D.C. (now the USGS) that worked to calculate least square's adjustments for triangulations in cartographic surveys conducted from the 19th century up through World War I. As these continental surveys were completed, scientific computing moved to least squares regression of econometric data in the U.S. Department of Agriculture (Figure 1). Human computers were also solving ordinary differential equations for astronomical tables at the Naval Observatory and artillery firing tables at U.S. Army Aberdeen Proving Ground.

Figure 1: A computing room at the USDA. [2]

The human computers gradually gave way to mechanical calculating devices that, during the period between the wars, increased in sophistication and size on a more or less evolutionary trajectory. Starting with the MIT Differential Analyzer, Grcar traces developments in terms of three key criteria: digital or analog, electronic or mechanical, and programmable or not. As machines grew larger they also grew more expensive even though, as Grcar noted, their development was usually not government funded. Thus, there was a machine built at MIT called the "Rockefeller" Difference Analyzer, named for the project's benefactor. There was also a famous falling out between Harvard University and IBM Corp. over Harvard's naming of a very expensive Navy-funded electro-mechanical machine the "Harvard Mark-I" in spite of the fact that IBM actually built it.

Computers continued to grow in size and complexity but their development was still evolutionary. None were at once electronic, digital, and programmable. The electronic stored-program digital computer as we know it today was invented by von Neumann and his (unacknowledged!) collaborators at University of Pennsylvania's Moore School of Electrical Engineering, as presented in von Neumann's "First Draft of a Report on the EDVAC" [3]. Grcar also noted that, in addition to the ostensible achievement of inventing the computer, von Neumann pioneered "Open Source" computing. Von Neumann freely distributed the First Draft [4] as well as more detailed plans for a computer built at Princeton's Institute of Advanced Study.

Grcar digressed frequently with entertaining tidbits from his history. One item of trivia for example: 2π was not always 360 degrees. It was 200 degrees Gauss's time. Another sidebar was Gauss's and Legendre's feud over credit for generalized linear models and the "least-squares" method. Gauss may have settled the matter, though, with the Gauss-Markov theorem, which provided the rigorous theoretical basis for using least squares. "Lacking justification, the only reason to minimize squares is convenience," Gauss scolded in Hamburg in 1809. And regarding von Neumann, Grcar related from the memoirs of mathematician Ida Rhodes that, in addition to his other numerous achievements, von Neumann earned a "constant " named after him:

> "... no matter when you asked them when the machine would be ready it was always 'in 18 months.' They started calling it the von Neumann constant." [5]

(The principle survives in software and many other fields of engineering today.) Another governing principle that Grcar wryly observed in his history of scientific computing was intellectual and technical inertia: "analog and mechanical computers were built for many years even after computers were invented."

As a computer person with fifteen years working with atmospheric simulation, I brought to Grcar's talk a certain reverence for von Neumann as one of the founders of both computing and numerical weather prediction -- but also came harboring some prejudice. I knew other accounts in which von Neumann was shown as more interested in wielding the weather as a weapon than predicting it:

> "As a committed opponent of Communism and a key member of the WWII-era national security establishment, von Neumann hoped that weather modeling might lead to weather control, which might be used as a weapon of war. Soviet harvests, for example, might be ruined by a US-induced drought." [6]

Although Grcar's did not touch on this, he provided me with a broader context in which to understand this aspect of von Neumann's personality and his place in scientific history. Taken in this context, I can appreciate that, first of all, in trying to sell weather as a weapon, von Neumann was only doing what so many scientists still do today: sell what they *really* want to work on as the solution to whatever problem of the day the government will fund. It's remarkable – and a tribute to the energy of creative minds in action – how readily, for example, the same basic science can be sold for environmental protection on the one hand and for homeland security on the other, all at the twist of a national agenda.

Secondly, von Neumann can not be pinned down so easily. He was apt to start a field like numerical weather prediction and then just as quickly move on to something else he found compelling. He was a founding member of the Institute for Advanced Study at Princeton and a force in starting a surprisingly large number of varied disciplines that he nevertheless abandoned after providing the seminal first push. Grcar claimed near the end of his talk that Von Neumann founded so many fields – from computer science to the mathematics of quantum theory to numerical analysis – that almost 1 in 5 of the total number of mathematical papers *ever* published might be attributed in some way to von Neumann (Figure 2).

Here, there were a few politely skeptical interjections from the audience. Grcar acknowledged the point was arguable but did not retract the claim. My own view on this – without any disparagement of Grcar's talk or his subject – is that the steady democratization of higher education (science in particular), the sheer increase in size of the world population, and the technical impetus of two great wars of unprecedented violence ensured there would be more scientists and typewriters in the Twentieth Century than during all preceding human history. So naturally, a raw count of papers gives the advantage to modern founders of disciplines; but here we grant speaker's prerogative of poetic license.

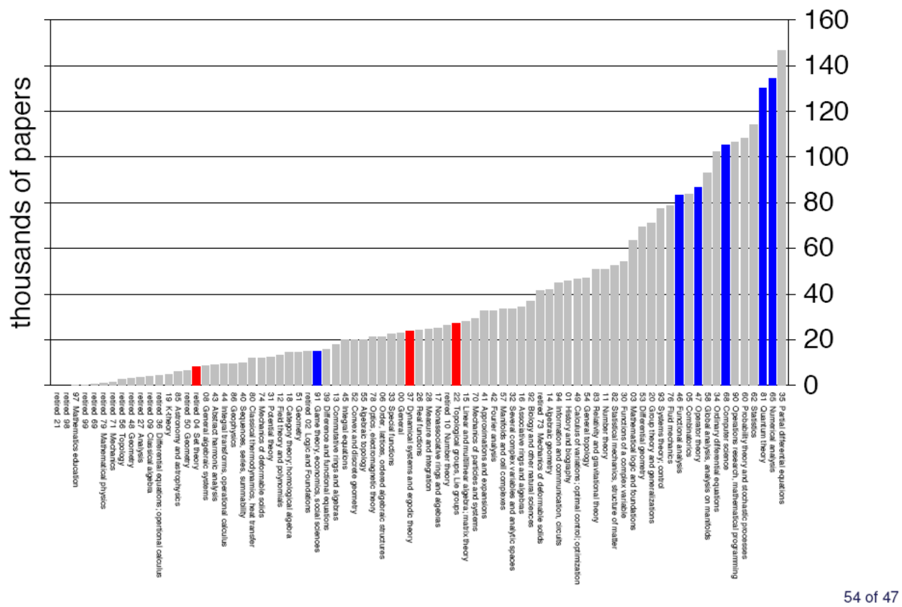

Figure 2: All mathematics papers through 2005 from "John von Neumann and the Origins of Scientific Computing", Joseph Grcar, CU Applied Math colloquium, September 21, 2007. [1] The highlighted columns are set theory, game theory, dynamical systems, topological groups, functional analysis, operator theory, computer science, mathematics of quantum theory, and numerical analysis. Those in blue are branches of mathematics in which von Neumann wrote the first paper; red are fields to which he made major contributions.

References and notes:

[1] An older version of the speaker's slides can be found here: http://seesar.lbl.gov/ccse/people/grcar/Talks/2007.05.22/2007.05.22.pdf)

[2] D. A. Grier, When Computers Were Humans, Princeton University Press, 2005.

[3] *First Draft of a Report on the EDVAC*, John von Neumann, Contract No. W-670 ORD-4926. Moore School of Engineering and University of Pennsylvania. June 30, 1945. http://www.virtualtravelog.net/entries/2003-08-TheFirstDraft.pdf

[4] http://en.wikipedia.org/wiki/First_Draft_of_a_Report_on_the_EDVAC .

[5] Ida Rhodes, Smithsonian Oral History Interview, 1973 as quoted by Grbac in [1].

[6] *Before 1955: Numerical Models and the Prehistory of AGCMs*, Paul N. Edwards, U. Michigan (http://www.si.umich.edu/~pne/sloan/prehistory.html). The quote is from "The Rise and Fall of Weather Modification: Changes in American Attitudes towards Technology," by C. Kwa in *Changing the Atmosphere: Expert Knowledge and Environmental Governance*, Clark Miller & Paul Edwards (eds.), MIT Press, 2001, Cambridge, Mass., pp. 135-165.