The Universal History of Numbers and *The Universal History of Computing*

Reviewed by Joseph Dauben

The main aim of this two-volume work is to provide in simple and accessible terms the full and complete answer to all and any questions that anyone might want to ask about the history of numbers and of counting, from prehistory to the age of computers.

—*Georges Ifrah,* The Universal History of Numbers *(Foreword)*

The final step in this technological advance was made when the microprocessor was introduced in 1971…

—*Georges Ifrah,* The Universal History of Computing *(p. 298)*

This is the second installment of a two-part book review. The first part appeared in the January 2002 issue of the *Notices*, pp. 32–38. In the review *Numbers* refers to Volume I and *Computing* to Volume II.

The Universal History of Numbers. From Prehistory to the Invention of the Computer (Volume I)
Georges Ifrah
Translated from the French by David Bellos, E. F. Harding, Sophie Wood, and Ian Monk
John Wiley & Sons, New York, 1999
xxii + 633 pages

The Universal History of Computing. From the Abacus to the Quantum Computer (Volume II)
Georges Ifrah
Translated from the French and with notes by E. F. Harding, Sophie Wood, Ian Monk, Elizabeth Clegg, and Guido Waldman
John Wiley & Sons, New York, 2000
410 pages

The Universal History of Numbers is full of detail, with charts and diagrams and the author's own hand-drawn illustrations. Its sequel, *The Universal History of Computing* (the volume under review here), seems something of an afterthought by comparison. There are no illustrations, no photographs, nothing to enliven the prose, which at times is plodding. For example, the translators surely could have found a more felicitous way to express Ifrah's characterization of writing systems than as providing "a visual medium to embalm human thought" (*Computing*, p. 3)! Indeed one of the points Ifrah makes repeatedly about the modern number system is that it led to great things—hardly the implication of "embalm".

The British edition of Ifrah's books appeared as a two-volume set, while the American edition is designed to look like two separate books. The title of the American edition of Volume II, *The Universal History of Computing. From the Abacus to the Quantum Computer*, also differs from the British title, which was *The Universal History of Numbers. The Computer and the Information Revolution.* This change, designed perhaps to appeal to American readers, makes it seem as if Ifrah's book were on the cutting edge of scholarship in the history of computing. But there is nothing to be found here at all on quantum computers—in fact Ifrah offers little in detail beyond introduction of the pocket calculator and thermal printers (*Computing*, p. 299).

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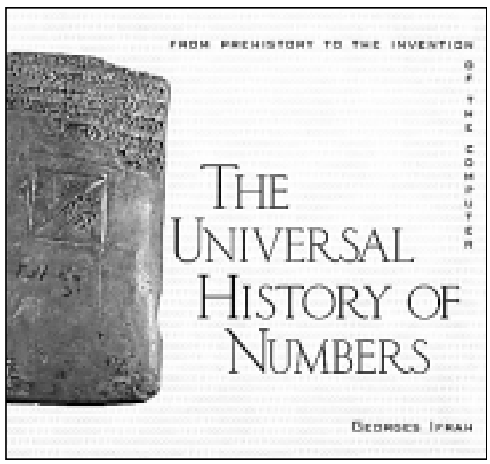
Although the American edition of *The Universal History of Computing* bears a publication date of 2000, Ifrah's account for the most part stops some thirty years ago, with the introduction of microprocessors in the mid-1970s. Thus many of the major advances of the past few decades are missing from this "universal" history. In describing different kinds of computers, Ifrah does mention briefly—in addition to electronic computers—mechanical, electromagnetic, pneumatic, and opto-optical computers, and also discusses the possibility of biochemical computers (*Computing*, pp. 302–3). But there is no hint here of quantum computers, and other omissions are just as surprising: There is no mention of Japanese efforts related to supercomputers, almost nothing on the importance of software in the computer revolution, and no discussion of the ways in which desktop and laptop computers have affected virtually every aspect of daily life. And for a book that purports to cover the information age, in which the Internet is synonymous with information, it is amazing that the Internet receives not a word of mention (the translators do add notes with references to information available on the World Wide Web (*Computing*, p. 344)).



The translators of Volume II seem to have sensed its problems, for not just occasionally, but time and again they step in to offer their own comments. They rightly point out difficulties of translation, such as the distinction between *computer* and *ordinateur* that is relevant in French but lost in English. More surprising is the need the translators often feel to explain, expand, or correct what Ifrah has written. Why didn't Ifrah's editors ask that he revise the English edition if such extensive editorial tinkering was found to be necessary?

The first example of the translators adding material occurs as early as page 2, but becomes increasingly intrusive in Chapter 3 ("From Calculation to Calculus"), where Ifrah is not entirely clear about the meaning of "calculation" and where the translators add more than half a page of further explanation. A paragraph later, Ifrah mentions the word "calculus" and then jumps to discussion of "tensor calculus". The translators again feel it necessary to intersperse a page outlining the basics of the differential and integral calculus and then to go on to explain what the tensor calculus is, because Ifrah does not (*Computing*, pp. 70–1). When Ifrah mentions Luca Pacioli, who wrote "an important book on arithmetic and algebra", it is the translators who indicate that this was the *Summa de Arithmetica* published in 1494 (*Computing,* p. 76).[1] When Ifrah says that René Descartes invented analytical geometry in 1637, it is the translators who explain what this was. And when Ifrah mentions that Nicolai Lobachevski and Wolfgang Bolyai invented non-Euclidean geometry (mistaking Wolfgang the father with János the son, who was the one to advance the idea of a geometry based on rejection of the parallel axiom (*Computing*, p. 82)), it is the translators who again provide the explanatory footnote (but without noting the mistake). Mathematicians of course will not need such explanations, but general readers for whom this book is intended will.

Sometimes the translators find it necessary to correct the author. For example, Ifrah states that in 1837 the American Samuel F. Morse used binary code to transmit messages by electrical impulse. As the translators point out, strictly speaking, Morse did not use a binary code, but a ternary system, in base 3, since the Morse code depends upon three signs, the dot, the dash, and the silence separating the sequences of dots and dashes encoding a given character.

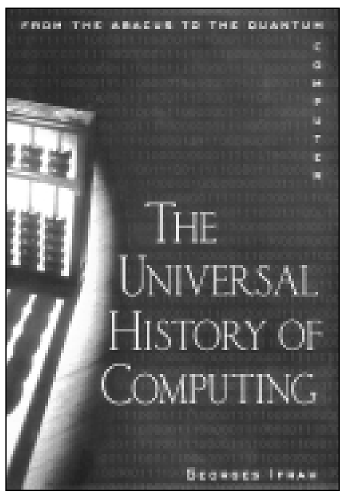
Ifrah leaves many substantial concepts unexplained, and the translators often feel obliged to offer more information. For example, at the beginning of Ifrah's account of analog computation devices, the translators add a helpful definition of what analog computation is. One of the earliest devices mentioned is the Antikythera mechanism (which Ifrah mistakenly refers to as the Antikythera (*Computing*, p. 155), as if the place where the orrery-like device was found in an ancient shipwreck off the island of Antikythera in Greece were indeed the object itself). With no evidence or explanation whatsoever, Ifrah suggests that this device of gears to replicate the motions of the planets "may possibly have been used in navigation" (*Computing*, p. 155).

Ifrah soon gets to more recent analog devices—like the slide rule—but again offers little in the

[1]*The translators also add that this was the first printed work on mathematics, but actually, the first was the Latin edition of* Euclid's Elements *by Campanus, printed by Ratdolt in 1482. Commercial arithmetics were printed as early as 1478, and the* Bamberger Blockbuch *was block printed sometime between 1471 and 1482, with the* Bamberger Rechenbuch *published in 1483. I am grateful to C. J. Scriba for bringing these details to my attention.*

way of helpful information. The following is typical of the presentation:

> The slide rule was invented in 1620 by the Englishman Edmund Gunter and enhanced around 1623 by William Oughtred. It was further improved by Robert Bissaker in 1654 and by Seth Partridge in 1671, finally receiving its modern form in 1750 at the hands of Leadbetter. As a matter of interest, while the slide rule had been introduced in France in 1815 by Jomard, it was judged too revolutionary at the time; only in 1851, when the mathematician Amédée Mannheim added further useful enhancements to it, did it take on [sic] with the French…." (*Computing*, p. 156)



This is also a very good example of how frustrating at times this book is to read, with its strings of dates and last names (assuming readers will be familiar with the likes of Leadbetter and Jomard), and without indications of what is at issue. Apart from problems with the translation (either the slide rule "caught on" or "took off", but it did not "take on"), surely most readers would like to know what made the slide rule seem so revolutionary in France, and what additions Mannheim made that were particularly useful. This same frustration was apparently felt by the translators, because several pages later, they provide an addendum of nearly four pages offering "principles and examples of analog computational devices" (*Computing*, pp. 163–7), including a brief but clear explanation of how the slide rule works. However, the various "improvements" to which Ifrah alludes are not described, nor is anything said about the French Revolution.

The Universal History of Computing is divided into two parts. Part One is a summary of the major results of Volume I, including a chronological summary recapitulating in a mere eighteen pages what Volume I covered in over 600! This is followed by more than forty tables classifying the world's many different number systems into three basic types (additive, hybrid, and positional), with various subcategories distinguishing minor variants. Unfortunately, the same mistakes or misinterpretations are repeated here as in Volume I, and more blatantly in some cases, as for example when Ifrah writes that between 2700 and 2300 BCE, the people of Sumer "invent their abacus", or when he says that the Zapotecs and other pre-Columbian cultures "make use of calculating instruments" because their base-twenty system is "ill-adapted" for calculation.

Two examples of how unreliable Ifrah's "chronology" can be are the entries for Dedekind and Cantor. Ifrah quotes Dedekind to the effect that "[t]he straight line is infinitely richer in points than the set of algebraic numbers is" (*Computing*, p. 84). This is a misquotation—Dedekind does not refer to algebraic numbers, but rather to the set of rational numbers (which were the elements of Dedekind's famous "cuts"—the means by which he rigorously defined the real numbers, something Ifrah does not mention). What is significant here is that Dedekind had no idea how much "richer" the set of real numbers really was. That understanding had to wait for Georg Cantor's proof that the real numbers are nondenumerably infinite.

Ifrah then gets the dating out of sequence, saying that in 1883 Cantor proved that the set of algebraic numbers is countable. This time Ifrah is right about algebraic numbers but wrong about the year—which was in fact a decade earlier, in 1873. In addition to proving that the algebraic numbers are denumerably infinite, Cantor ended his paper (published in 1874) with his truly revolutionary proof that the *real* numbers are *nondenumerably* infinite—something Ifrah never mentions! It is surprising that there is also no mention of Cantor's later use of the diagonalization method to again establish the nondenumerability of the real numbers (and the existence of even higher powers of transfinite sets) in 1891, or the continuum hypothesis (though Ifrah does include an entry in his chronology for 1931 mentioning Gödel and his Incompleteness Theorem).

In what is called a "tailpiece" to this section, apparently added by the translators, a short paragraph calls attention to the fact that "we have now met the five fundamental numbers of mathematics, 0, 1, e, π and i" and notes these five numbers have a startling relationship: $e^{i\pi} + 1 = 0$. But this is offered with absolutely no explanation of why such a relationship should exist or of what its truly remarkable features are (p. 85). And this time the translators do not attempt to make up for the omission.

As if acknowledging the hopelessness of his chronology of the major steps "from calculation to calculus" when it comes to the first half of the twentieth century, this is—*verbatim*—what Ifrah writes:

> This period saw fundamental contributions from Western mathematicians

> and logicians to the development of contemporary mathematics and logic, especially in the areas of algorithmic logic and symbolic calculus. Notable figures in this history are G. Frege, G. Peano, B. Russell, A. N. Whitehead, D. Hilbert, E. Zermelo, E. Steinitz, R. Carnap, E. Artin, K. Gödel, E. Post, S. C. Kleene, A. Turing, A. Church, J. von Neumann, A. A. Markov, P. S. Novikov, H. Cartan, C. Chevalley, J. Delsarte, J. Dieudonné, A. Weil; and of course many others. (*Computing*, p. 85)

And that is all Ifrah has to say. If these are among the most prominent mathematicians and logicians who made "fundamental contributions" in areas relevant to Ifrah's project, it would be reasonable to expect more details to come up, if not now, then surely later. But the hopeful reader turning to the index will be disappointed to find that *nothing* is listed there for Frege, Zermelo, Steinitz, Carnap, Artin, Post, Kleene, Markov, Novikov, Cartan, Chevalley, Delsarte, Dieudonné, or Weil. Why parade all these names if nothing more about them is to be said? Without some explanation of the accomplishments of these "notable figures", this is an otherwise meaningless succession of names.

Later in the book, Ifrah again uses this same approach in an impossible attempt to cover the course of mathematics from classical algebra to set theory in a very brief two pages. After describing developments from Cantor and the origins of set theory to lattice theory, general topology, and the theory of categories, Ifrah presents a list of mathematical areas, about which he comments:

> This list quite simply gives the names of some of the countless areas which modern mathematics has explored with new and fascinating techniques for whoever takes the trouble of mastering them. It is nevertheless amply sufficient to provide an understanding of how much these new concepts, marked by the growing importance attributed to set theory, have radically altered the very spirit of the science of mathematics. (*Computing*, p. 260)

But this verges on parody. Ifrah provides nothing more than the names of these mathematical areas; he alludes to "techniques" but does not describe what they are or why they are so significant. This provides no insight about how such concepts altered mathematics, nor does it provide anything to interest or enlighten the reader.

Moreover, Ifrah clearly does not have a good understanding of set theory or its history. Without citing his sources, Ifrah explains that "[t]hus axiomatics was created by Cantor for sets, and by Hilbert for geometry" (*Computing*, p. 263). Not only did neither of these great figures create axiomatics, but Cantor never treated his theory axiomatically—in his hands it always remained a naive theory. And surely Ifrah knows that it was Euclid and his Greek progenitors who created axiomatics for geometry; what Hilbert did was to axiomatize geometry in a way that he hoped would make it possible to prove its consistency. Ifrah never gets to such levels of detail or significance.

Calculators and Computers

Part Two of *The Universal History of Computing* consists of three chapters: "From Clockwork Calculator to Computer: The History of Automatic Calculation", "What is a Computer?", and "Information, the New Universal Dimension". These chapters address the volume's main subject, but it is territory on which Ifrah is not very sure of himself.

Unexpectedly, Ifrah himself admits to some misgivings: "I have, over many years, hesitated long and often before publishing the account which follows. I have held back for so long as the ideas which I expressed were still no better structured than the accounts in sundry 'static' histories, mere accumulations of fact but not co-ordinated on the historical scale" (*Computing*, p. 109). But in fact, what appears here is still largely unstructured, a mix of material snipped and quoted from various sources, more secondary than primary, and mostly lacking either technical or historical perspective. A couple of brief examples will give a sense of the truly "universal" problems with the presentation Ifrah offers.

Despite Ifrah's wish to go beyond the "static histories", his account of the evolution of the computer is basically a prosaic one, starting from the earliest calculating machine designed by the German astronomer Wilhelm Schickard in 1623, and continuing to the first machines to survive to the present, those of Pascal and Leibniz. Charles Babbage receives considerable space, but the development of true computers is a twentieth-century story. As Ifrah says, Babbage's dream became reality with the Mark I at Harvard, built by Howard Aiken. Typically, much of Ifrah's treatment is unsatisfyingly vague. Ifrah says that Aiken "was faced with a set of complex mathematical problems whose solutions would have required an inordinate amount of time by human hand alone." What problems Aiken faced, and how they may have influenced development of the Mark I, Ifrah never says. He does point out the limitations of the slowness of the Mark I as an electro-mechanical calculator, a limitation overcome in the Mark II and successive generations that moved entirely to electronic computing. The first completely electronic, multipurpose, analytical calculator was the American ENIAC (Electronic Numerical Integrator and Computer).

Ifrah covers many of the basic computers that were coming onto the scene in the 1940s and 1950s—BINAC, EDVAC, SEAC, UNIVAC, MADM, EDSAC, LEO, etc.—but does not mention my personal favorite, von Neumann's Mathematical Analyzer, Numerical Integrator and Computer (MANIAC). In a book replete with acronyms throughout, a glossary would have been helpful. American readers can be assumed perhaps to know what IBM and UNIVAC represent, but what about the machines from France that Ifrah naturally introduces? For example, he discusses the development in the 1950s of the SEA analog computers, including the ANALAC built by CSF. None of the acronyms are defined or explained, and none appear in the index.

Incompleteness

One problem with Ifrah's presentation is that facts are often listed as if he were assembling a mass of information collected on note cards. Usually there is no interpretation or analysis of the significance of the items strewn about one after the other. To give but one example, in a very condensed summary of advances made in computing in the U.S. in the 1950s, Ifrah mentions the Whirlwind I at the Massachusetts Institute of Technology, "another computer based on the plans of von Neumann" (*Computing*, p. 294). It was conceived under the direction of Jay W. Forrester and had "a magnetic-core memory, a graphics printer, remote user interaction system,…, etc." What the "etc." means is unclear, and most of this will be meaningless to anyone not already conversant with the basics of computer engineering and the Whirlwind I. It should at least have been pointed out that what was truly innovative about Forrester's Whirlwind was the invention of the coincident-current magnetic core memory (developed with Jan Rajchman of RCA), which for the first time allowed computers to be built with very large storage capacities.

Ifrah also misses one of the most interesting points about the first public application of UNIVAC, when "it was used on CBS television for opinion polls during the presidential elections of 1952, accurately predicting Eisenhower's victory" (*Computing*, p. 294). That it did, but there is more to the story. Nationwide polls had forecast a nose-to-nose race between Dwight D. Eisenhower and Adlai Stevenson. The UNIVAC programmers were so aghast at the landslide the computer initially predicted (forty-three states and 438 electoral votes for Eisenhower) that they pulled the plug on UNIVAC and repeatedly reprogrammed the computer until it predicted twenty-four states for each candidate, with an electoral vote difference of 270 for Eisenhower, 261 for Stevenson. This was an outcome too close to call, as CBS news then reported. Only later, after the official precinct-by-precinct counts had been reported, was the truth admitted and the original UNIVAC prediction allowed to stand, with some difficult explaining to do. As the Jacksonville, Florida *Journal* headlined the next morning: "Machine Makes a Monkey out of Man," (Wulforst, p. 170).

Quantum Computing, Information, and Human Intelligence

As *The Universal History of Computing* comes to an end, Ifrah seems to have run out of energy or lost interest. The last chapter, prior to Ifrah's conclusion, is called "Information, the New Universal Dimension" and offers little more than a pastiche of the views of others. One would expect that, as Ifrah reaches his conclusion, "Intelligence, Science, and the Future of Mankind", he would make an attempt to tie everything together. But rather than speak for himself, he again leaves the writing to others. "To unravel this story of human intelligence our best option in this concluding chapter has been to have a number of significant authors speak in their own words, which we have collated into a sort of mosaic" (*Computing*, p. 348). He then presents a rag-tag collection of such authors as Molière, d'Alembert, Gonseth, Bergson, Piaget, Ellul, Brunschvicg, Comte, Hadamard, Poincaré, Bachelard, Blondel, Lévi-Strauss, and Rabelais (to list only a few of the French authors cited). More satisfying would have been a critical analysis and discussion of the most recent work of the past decade on the subject of information.

Responsibility

In reflecting on the course of this review, I want to end with some personal observations about the obligations of writers, publishers, editors, and reviewers to their respective audiences. As George Sarton once advised in a notice about how to write a book review, no one who has ever written a book should be taken lightly (Sarton, pp. 155-156). It is a tremendous amount of work to get anything into print. A book is the result of a collaborative effort among authors, publishers, editors, printers, and ultimately, the public that purchases the final product. But authors, editors, and publishers share an important responsibility in this process—to be sure that the subject matter is treated accurately and that the book does not create false impressions about what it achieves. On both counts it seems clear that neither Ifrah nor his editors and publishers have served their readers well. Despite Ifrah's obvious enthusiasm for his subject, what he has written cannot be regarded as reliable or "universal".

A nonspecialist who writes for a popular audience about very technical matters needs more than enthusiasm for his subject to earn the confidence of his readers. Here too, editors and publishers bear responsibility. Did the original French publisher, Editions Robert Laffont, or subsequently the Harvill Press in Britain or John Wiley & Sons in the U.S., actually refer Ifrah's manuscripts to any serious experts in the history of mathematics? This hardly seems possible. The lack of expert evaluation no doubt helps to explain why a group of French academics felt it was necessary, and indeed was their obligation, to collaborate in making clear Ifrah's dangerous disregard for the most recent research and scholarship (see the references in the first part of this review). Furthermore, the numerous additions, explanations, and corrections offered by the translators in Volume II should have alerted Ifrah's editors to problems that the author could have addressed as the books were being translated, especially in light of the strong criticism Volume I received in France.

Potential readers should in turn be wary of reviews of such books by nonexperts. The newspaper critics quoted on the books' dust jackets may have been impressed, but those critics were clearly not aware of the scholarship of experts—scholarship Ifrah has exaggerated, misinterpreted, ignored, or failed to consult. Insuring the integrity of the finished work is especially important with books like Ifrah's, because the background necessary to judge them is well beyond the capacity of ordinary readers, who are unlikely to be able to spot his inaccuracies and inflated claims.

For its part, John Wiley & Sons has made clear it accepts no responsibility for the contents of Ifrah's books: Tucked away on the back of each title page is a disclaimer I have never seen in a book before (though the publisher says it appears in all Wiley books as a matter of course). The disclaimer reads:

> This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold with the understanding that the publisher is not engaged in rendering professional services. If professional advice or other expert assistance is required, the services of a competent professional person should be sought.

In other words, *Caveat lector.*

References

[1] George Sarton, Notes on the reviewing of learned books, *Isis*, **41** (1950), 149–158.

[2] Harry Wulforst, *Breakthrough to the Computer Age*, Charles Scribner's Sons, New York, 1982.