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CERTAINTIES AND DOUBTS IN WORLD FAIR COMPARISONS OF COMPUTING ARTIFACTS[1]

Introduction: Nobert Wiener's 1956 comparison

The contemporary classification of computers under a digital and an analog class, and the associated devaluation of the analog as being, supposedly, technically inferior, goes back to the period between the 1940s and the 1960s. During these years, an essentialist demarcation between the digital and the analog became possible by decontextualized comparisons. This demarcation has since been projected to the history of computing before the 1940s. In several of the influential comparisons of the post-World War II period, the slide rule was singled out as a representative of the analog computer, and a desktop mechanical calculator (also called a calculating machine) as a representative of the digital computer. We may turn to Nobert Wiener, the celebrated father of cybernetics, for an example of a decontextualized comparison of the two that comes from this period (1956):

> An example of an analogy machine is a slide rule, in contrast with a desk computing machine which operates digitally [...] Those who have used a slide rule know that the scale on which the marks have to be printed and the accuracy of our eyes give sharp limits to the precision with which the rule can be read. These limits are not as easily extended as one might think, by making the slide rule larger. A ten foot slide will give only one decimal point more accuracy than a one-foot slide rule, and in order to do this, not only must each foot of the larger slide rule be constructed with the same precision as the smaller one, but the orientation of these successive feet must conform to the degree of accuracy to be expected for each one-foot slide rule. Furthermore, the problems of keeping the larger slide rule rigid are much more greater than those which we find in the case of the smaller rule, and serve to limit the increase in accuracy which we get by increasing the size. In other words, for practical purposes, machines that measure, as opposed to machines that count, are very greatly limited in their precision[2].

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[1] The material discussed here was located while Aristotle Tympas was conducting research that was supported by fellowships from the IEEE History Center and the National Museum of American History at the Smithsonian Institution.
[2] N. Wiener, *The Human Use of Human Beings,* Garden City, New York: Doubleday Anchor, 1956, pp. 64-65.

The accuracy of the slide rule could actually increase without an increase in its size. This was possible by the addition of a magnifying cursor, of certain computing scales, of certain marks, and by many other techniques. Let us, however, agree that the only way to increase the accuracy of the slide rule was by a corresponding increase in its size. Let us also assume that other computing variables (portability, speed, cost, etc.) did not matter[3]. What strikes us here is that Wiener did not explain why the technical limits of the slide rule were not shared by the desktop machine. Moreover, he mentioned nothing about how to increase the accuracy of the desktop machine. Finally, despite what he promised to do, Wiener didn't offer a comparison in terms of "practical purposes". In doing so, he assumed that which had to be proven, namely that a desktop machine was different from (and superior to) the slide rule.

Wiener, who knew of the importance of computing with a slide rule during World War I – he had actually called World War I a "Slide Rule War", had, however, some doubts. He revealed them below in his book, while referring to some "prejudices" about computing techniques: "[a]dd to this the prejudice of the physiologist in favor of all-or-none action, and we see why the greater part of the work which has been done in the mechanical simulacra of the brain has been on a machine that are more or less on a digital basis"[4].

In what follows, we look at World Fair comparisons of computing artifacts in order to understand both the meaning of the digital-analog demarcation and the ideological mechanisms (certain rhetoric and display practices) by which it was prepared. The importance of World Fairs for promoting an ideology of social progress in general, and, technological progress in particular, has been shown by many historians[5]. In our case, we are interested specifically in how some computing artifacts were ideologically presented as superior to others[6].

Frederick Barnard's 1867 comparison

A suggestive early comparison of computing artifacts was offered by Frederick A.P. Barnard, President of Columbia College and United States commissioner to the 1867 Paris Universal Exposition. It was included in his thirty-six page long chapter on artifacts of "Metrology and Mechanical Calculation". In his extensive history of mechanical calculation, Barnard briefly surveyed the history of the slide rule. "In theory", stated Barnard, "its powers are very great; in practice they are comparatively

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[3] For a review of techniques that could increase the accuracy of the slide rule without increasing its size, and for the importance of variables other that speed, see A. Tympas, Ph.D. Thesis, *The Computor and the Analyst: Computing and Power, 1870s -1960s*, Georgia Institute of Technology, Atlanta 2001.

[4] N. Wiener, *The Human Use of Human Beings*, p. 65. For Wiener in World War I, see T. Wyman, "Norbert Wiener and the Slide Rule or How American Mathematicians Came of Age", *Journal of the Oughtred Society* **10** (Spring 2001) pp. 46-47.

[5] For an introduction to the vast relevant literature, see R.W. Rydell and N.E. Gwinn eds., *Fair Representations: World's Fairs and the Modern World*, VU University Press, Amsterdam 1994.

[6] For an early historiographical call to pay attention to the beautified presentation of technology at World Fairs, see B. Sinclair, "Technology on its toes: Late Victorian ballets, pageants, and industrial exhibitions", in: *In context: History and the History of Technology. Essays in honor of Melvin Kranzberg*, S.H. Cutcliffe, R.C. Post eds., Lehigh University Press, Bethlehem 1989.

limited, from the facts that divisions must be either small, or the dimensions of the instrument itself be too great for convenience". "The circular form", he added, "possesses the advantage of admitting a greater length of scale conveniently within the reach of the operator; but still, without greatly exceeding the dimensions to which, for any practically useful purpose, such a machine must be limited, it is impossible to secure results which can be relied on beyond three places of figures." Barnard then decided to devote several pages of his report in order to explain the technical superiority of the Arithmometer, the first functional calculating machine. Calculating machines, also known as computing machines, mechanical calculators and desktop machines, are now considered to be an exemplar of pre-World War II digital computers; slide rules of analog computers[7].

In describing the slide rule, Barnard placed the emphasis on sliding. He referred to it as "two rules sliding side by side" or "sliding rules" in the form of concentric circles. He described the slide rule only once, because there was no internal and external view of it. On the other hand, Barnard provided with a double description of the mechanical relationships materialized in the Arithmometer: one as they could be seen from the outside and one as they could be seen from within, one external and one internal. The two were divided by the encasement of a certain part of the calculating machine. As far as the external view goes, Barnard reported that the Arithmometer "was constantly the center of the curious crowd" at the 1867 Fair. What the crowd could see was what we would now call a "black box": "The *arithmometer* of Mr. Thomas", wrote Barnard, "presents, externally, the appearance of a neatly finished box". Like the sliding rule, the Arithmometer was set up by sliding. Barnard stated that the "setting of the machine" was done by "sliding the indexes" (a rule or scale was called, among other things, an index). But the similarity in setting the slide rule and the calculating machine was not apparent to an external observer: in computing with the Arithmometer the effect of sliding was not seen publicly[8].

"So much for the machine as it appears to the spectator", continued Barnard by moving to an internal description of the Arithmometer, "now for the transmission of motion": "It will now be seen what is the effect of sliding the indexes as described above in the setting of the machine." As we understand it, in both cases, the human user set up the computing artifact in a certain position by the proper sliding of indexes. The human user then moved on to read the result. There was, however, one notable difference: unlike the calculating machine, the slide rule was not encased and the effect of sliding was publicly viewed. As a result, it was clear that it was the user (through sliding) produced the result by setting up the artifact. When part of this production process became private by being encased into a box, the producer of the computation was still the human who slid the linked indexes. This, however, was no longer publicly visible in the case of computing with a calculating machine. As with all capitalist production, in producing with a calculating machine the human was removed from

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[7] See F.A.P. Barnard, *Paris Universal Exhibition, 1867: Report on Machinery and Processes of the Industrial Arts and Apparatus of the Exacts Sciences*, Van Nostrand, New York, 1869, pp. 636 and 638-639. For the context of the introduction and use of the Arithmometer, see A. Warick, "The Laboratory of Theory or What's Exact About the Exact Sciences?", in: *The Values of Precision*, M.N. Wise ed., Princeton University Press, Princeton 1994, pp. 311-351.
[8] See F.A.P. Barnard, *Paris Universal Exhibition*, 1867, p. 631.

public view to make it appear as if the source of computing value was the calculating machine, not the human who calculated with it[9].

Below, however, in his report, Barnard expressed some doubts about the Arithmometer. In the history of the calculating machines, the most difficult issue had to do with the proper "carrying" of the digits. The critical component of the calculating machine is the "carrying mechanism", usually known as the "acccumulator". In the words of Barnard, "it is important that the resistances [to sliding] should not be allowed to accumulate. This is prevented by making the movements consecutive and simultaneous." After reviewing the development of calculating machines in general and the Arithmometer in particular, Barnard argued that in an "efficient calculating machine" additions are simultaneously made to all the dials. This, however, went against the consecutive motion because "if, in carrying, each [of the simultaneous additions to dials] acts directly on the next, its action will often arrive at a time when that one is in motion, so that the two actions will interfere, or the *carrying* action will fail to take effect." Earlier Barnard had dismissed Musina's machine in favor of the Arithmometer. The machine of Opradino Musina, of Mondovi, Italy, was the only other artifact exhibited under the class of calculating machines. Barnard had previously wondered if "[t]his little contrivance hardly deserves, perhaps, to be called a machine". After admitting the problem with sequential computing, he came back to the Musina artifact: "[t]he only remedy, while this direct action of one dial upon another is maintained as part of the system, is to cause the dials to move successively, as in the machine of Musina; an expedient which so far protracts the time of operation as to neutralize in great measure the advantage."[10]

The terms serial-sequential and parallel-simultaneous computing are now employed in reference to digital and analog computing respectively. In computing with a slide rule, the user could determine at which number the sliding must stop. In computing with a calculating machine, he could not do so because of the encasement. Put differently, the user could intervene in parallel to the open sliding of the slide rule but he could not intervene in parallel to the encased sliding of the calculating machine. As in choosing between mass and flexible production in general, the tradeoff between the efficiency of the sequential and the flexibility of parallel computation, i.e., the dilemma between automation and adaptability, was inescapable. The promoters of the electronic computer never solved the sequential-parallel computing dilemma that was inherited to them from the earlier history of computing. The dilemma marked the history of electronic computing since then, manifesting itself in several debates, form the analog-digital debate of the 1940s -1950s to the 'connectionists' – 'representationistists' debate of the 1980s -1990s[11].

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[9] *Ibid.*, p. 640.

[10] *Ibid.*, p. 641, p. 638, and p. 645.

[11] For the transmission of the serial-parallel dilemma from mechanical to electronic era computing, see P. Ceruzzi, "Crossing the Divide: Architectural Issues and the Emergence of the Stored Program Computer, 1935-1955", *IEEE Annals of the History of Computing* **19** (1997) pp. 5-12.

Percy Ludgate's 1914 comparison

1914 is a key year in the history of computing at World Fairs. It is the year of the first World Fair that was devoted exclusively to the exhibition of computing artifacts. In his introduction to calculating machines in the handbook of this exhibition, which took place in Edinburgh, F.J.W. Whipple excluded the slide rule but not because it was a calculating machine. He did so because he thought that it was not a "purely arithmetical" calculating machine. We suggest that the slide rule was not a "purely arithmetical calculating machine" because there was no encasement to purify the product (number) by concealing the process of its production. Whipple included in his article a description of a version of an Arithmometer, which was part of the exhibits from the University of the Edinburgh mathematical laboratory[12].

Interestingly, P.E. Ludgate, another contributor to the section of the 1914 Exhibition handbook on calculating machines was not very satisfied with calculating machines like the Arithmometer. The title of his contribution was "Automatic Calculating Machines." For Ludgate, the Arithmometer was not an "automatic calculating machine". For him, it was doubtful that any of the existing calculating machines actually was:

> Automatic calculating machines on being actuated, if necessary, by uniform motive power, and supplied with numbers on which to operate, will compute correct results without requiring any further attention. Of course many adding machines and possibly a few multiplying machines, belong to this category but it is not to them, but to machines of far greater power, that this article refers. On the other hand, tide predicting machines and other instruments that work on geometrical principles will not be considered here, because they do not operate arithmetically. It must be admitted, however, that the true automatic calculating machine belongs to a possible rather than an actual class; for, though several were designed and a few constructed, the writer is not aware of any machines in use at the present time that can determine numerical values of complicated formulae without the assistance of an operator[13].

Like Barnard, Ludgate would like both the adaptability of what we now call the analog and the automation of the digital. "The first great automatic calculating machine", argued Ludgate, "was invented by Charles Babbage". "I have myself", he continued, "designed an analytical machine, on different lines from Babbage's to work with 192 variables of 20 figures each". Even after the number of variables and figures was reduced from infinity to 192 and 20 respectively, Ludgate had to admit that he had not been able "to take any steps to have the machine constructed"[14].

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[12] For Whipple, see A. Warick, The Laboratory of Theory or What's Exact About the Exact Sciences?

[13] For the passages by Whipple and Ludgate, see E.M. Horsburgh ed., *Modern Instruments and Methods of Calculation: A Handbook of the Napier Tercentenary Exhibition*, Bell and Sons, London 1914, pp. 69 and 124. For Ludgate, see B. Randell, "From Analytical Engine to Electronic Digital Computer: The Contributions of Ludgate, Torres, and Bush" in: *Annals of the History of Computing* **4** (1982) pp. 327-341.

[14] See E.M. Horsburgh ed., *Modern Instruments and Methods of Calculation: A Handbook of the Napier Tercentenary Exhibition*, Bell and Sons, London 1914, p. 127.

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