MACHINES & MATHEMATICS[1]

LIESBETH DE MOL[*] & MAARTEN BULLYNCK[**] & MARIE-JOSÉ DURAND-RICHARD[***]

Modern historiograpy has shown us that the traditional image of the « mathematician at work », where he is represented as a solitary worker bent over his desk and surrounded by paper and writings tools, does not correspond to the daily reality of mathematical practice at all. The mathematician has to be seen as an actor in a social, economic and political context, communicating with his colleagues through conversation, writing, printed texts or through teaching and education. More even, there is always a technological dimension to his/her everyday work. Beyond paper and ink, other instruments are present too, influencing mathematics – and reciprocally, mathematics influencing the instruments. In more recent times, this influence has become more clearly visibile et has become important because of the multiple usages of the computer in mathematics. This has led mathematics such as Jonathan Borwein to claim that the computer have changed the way of doing mathematics[2]. Indeed,

[1] This issue is the result of a symposium organised by Liesbeth De Mol, Marie-José Durand-Richard and Maarten Bullynck during the *24th International Conference for the History of Science and Technology* (ICHST) at Manchester in 2013. The symposium's title was "Mathematics and machines : Explorations of machine-assisted mathematics since 1800” and proposed to open up new perspectives on the history of mathematics by examining how machines had been invented, developed and used to obtain mathematical results. Peggy Kidwell, Johannes Lenhard, Helena Durnova, Ulf Hashagen, Loic Petitgirard, Marie-José Durand-Richard, Alan Olley, Maarten Bullynck, Mark Priestley, Stephanie Dick, Wolfgang Brand, Edgar G. Daylight et Renate Tobies talked at the symposium, see BULLYNCK, DE MOL & DURAND-RICHARD, 2013.

[*] Liesbeth De Mol (*1977) studied archeology, art history and philosophy in Gent and defended her PhD *Tracing unsolvability: a mathematical, historical and philosophical analysis with a special focus on tag systems* in 2007. Since 2013 she is a CNRS researcher at Université de Lille. Her work focuses on computability, early computer usages and the epistemological and historical connections between formalization and computer engineering. She is the founding president of the inter-divisionary DHST/DLMPST commission for the history and philosophy of computing (HaPoC). She is currently coordinating the ANR-funded research project PROGRAMme on the question « what is a computer program ? ».

[**] Maarten Bullynck (*1977) studied mathematics, German languages and media studies in Gent and Berlin. He defended his PhD *Vom Zeitalter der formalen Wissenschaften. Parallele Anleitung zur Verarbeitung von Erkenntnissen anno 1800* in 2006. From 2007 to 2008 he was a fellow of the Alexander-von-Humboldt-Stiftung with a project on J. H. Lambert, including the development of a website featuring Lambert's collected works. Since 2009 he is maître de conferences at the Département de mathématiques et histoire des sciences at Université Paris 8. He publishes on the history of number theory, on the history of computing and on scientific communication in the 18th century.

[***] Marie-José Durand-Richard (* 1944) is a historian of mathematics. She has taught at the university of Paris VIII and she is currently associated researcher at the research unit SPHERE (UMR 7219 CNRS & Université Paris-Diderot). She is interested particularly in the English school of algebra and logic of the early 19e century, in the historiography of algebra and arithmetic, in the history of cryptography and the mechanisation of computation and its application (planimetres, differential analysers).

[2] BORWEIN & BAILEY, 2004.

calculating instruments do effectively change the way mathematical knowledge is produced and/or transformed.

However, this alleged revolution, as all revolutions, is neither new nor unexpected. It rather is the results of a long and complex evolution. To put this « revolution » in historical and critical perspective, this issue will reexamine more carefully the history of the interactions between mathematicians and their instruments and machines. This fresh view will allow to articulate certain recent developments, such as computer-assisted mathematics or experimental mathematics, as parts of a longterm history. Putting these evolutions in their context(s) and their specific historical sequence(s) will allow to reconstruct the long process that begins with the first industrial revolution and that runs into the digital era, showing that the computer is not a discrete transition, but rather part of a continuous evolution.

The articles in this issue concentrate on the period just before and after the Second World War, a key period when the interrelation between mathematical and technological developments evolves as a response to the threats of the war and their consequenes. Different mathematical practices co-exist and develop during this period, whether manual practices, machine-assisted practices or fully automated practices. All these are part of a continuous development of *manual practices of computation* (often assisted with mechanical calculators and numerical tables). that had been put into place, and had partially been standardised, in the beginning of the 20th century[3]. At the same time, more elaborate calculation instruments or machines had been constructed in the 1930s to help in numerically solving systems of differential equations. These *analogue instruments*, the differential and harmonic analysers, were of interest not only to scientific but also to industrial and military research. The numerical solution was effectuated through the representation of differential equations through physical processes, that were materialised mostly by mechanical or electrical connections, and through storing measurements (or tracing graphs) taken during the course of this process. From the 1930s onwards, yet another form of computation, next to manual and analogue computation, appeared, *mechanised and/or automated calculations* as performed by discrete or digital machines that are now considered as the precursors of today's *digital computers*. At first these machines were controlled by circuits of electromechanical relays, but they become more important through their electronic implementation, by vacuum tubes originally, later on by semiconductor technology. This technological innovation produced a speed of computation that was a hundred to a thousand times faster than all other forms or techniques of computation available before the Second World War. Nevertheless, this increase in speed, as well as the automation of the machines, also forced the development of new means, both material and conceptual, to program computational processes, without those, the first computers would have lacked in efficiency and usability.

Contrary to the view long held by the classic historiography of computing, the emergence of the digital computer does not make other, older modes of computations, such as manual or analogue ones, disappear. Rather, they continue to co-exist alongside each other, with numerous transfers between them[4]. These transfers may be mathematical methods, but also the organisation of computations or certain conceptual innovations. Moreover, there are a lot of crossovers between these three modes of calculation (manual, analogue and digital). System configurations where an analogue machine communicates with a digital computer, and where a human operates manages, complements and interprets the results, are frequently found.

3 See for instance Grier, 2005 or Croarken, 1990.

4 For the co-existence of analogue and digital computing, see Small, 2001 and Mindell, 2003.

The first four articles of this issue study these interactions between these three modes of computation between the 1920s and the 1960s. These case studies show how in different places, new technologies are set to work for numerical computation, and how computational methods are developed accordingly. Their usage opens up a new field of interactions featuring the parallel development of algorithms and the first concepts of programming.

In the first article, Maarten Bullynck focuses on one place of production, Aberdeen Proving Ground in Maryland (USA). He shos how the organisation of manual calculation that was put into place after the First World War serves as the blueprint for further mechanisation of ballistic computations. At first, alongside manual calculation, analogue computation is sponsored by the military. With the entrance of the U.S.A. in the Second World War, this evolution accelerates. As ballistic technology improves and complexifies, the need for more computations is felt, both quantitatively and qualitatively (e.g. precision). To meet those new demands, the army orders new machines that are able to automate the computational process, including the manipulation of numerical tables and decision making. With electromechanical machines such as the Bell Models III or V or with electronic machines such as ENIAC begins a slow transformation of the computational organisation. Instead of reproducing the manual organisation of computation, a new organisation, both autonomous and automated, becomes necessary. The planning of a completely automated computation will appear to be a difficult problem and will later on lead to the birth of automatic programming.

Marie-José Durand-Richard in her article studies a parallel case. She puts Douglas R. Hartree's work into context. Hartree was a go-between in matters of numerical analysis between the U.K. and the U.S.A. He was a physicist specialised in crystallography and a very able numerical analist, especially in numerically solving non-linear differential systems. He was the first to develop a differential analyser in the U.K., after visiting Vannevar Bush who had built such a machine in the U.S. Hartree adapted and renewed mathematical techniques to use them on a machine. He was part of the English war effort and at the end of the Second World War one of the first non-Americans that were able to use the ENIAC, one of the world's first digital and electronic computers. This experience led him to reconsider numerical approximation methods and develop programming strategies. He would become one of the driving forces behind the construction and usage of the first British computer, the EDSAC, at Cambridge. He was also one of the founding figures of the new mathematical discipline of numerical analysis.

Astronomy is one of the disciplines that has had always needed a lot of calculations. In the third article of this issue, Allan Olley studies the co-evolution of theoretical models of lunar motion with practical schemes to compute their solutions using machines. He shows how, throughout his carreer, the astronomer Wallace Eckert drew on the newest computational technologies, especially those from IBM. Already in the 1930s, Eckert had tried to reanimate a computational scheme developed by George B. Airy in lunar theory using accounting machines. After the war, Eckert tried to do these computations on the next generation of IBM machines (SSEC, IBM 650, IBM 701 et IBM 7090), adapting and improving the approximation methods to solve linear systems with hundreds or even thousands of unknowns. Near the end of his life, Eckert changed his basic model and took up the Brown-Hill model again, which he had studied as a student of Brown using manual calculation. This last work used the big IBM mainframes of the 1970s.

Finally, the fourth article by Loic Petitgirard studies the work done at the Centre de Recherche en Physique in Marseille in the 1950s. Instead of using the first digital computers, the work in this center built upon the development and usage of analogue devices. The Centre's director, Théodore Vogel, was a specialist in dynamical systems and had developed a mathematical epistemology that stood for an « experimental » approach to study complex systems. Altough this approach contrasted with the then influential Bourbaki mathematics, the Centre was not isolated. Also through the organisation of conferences in 1951 and 1964, it was part of an international research movement that mixed mathematics with engineering and that lived from the encounter between digital and analogue computing.

The issue closes with a critical overview of research in the history of the computer and of computing. This overview sketches the devlopment of the historiography of computing through an analysis of its relations with the history of mathematics. The importance of scientific computation for the early years of the digital computer, combined with the prestige of mathematics history in the 1960s and 1970s, made the history of mathematics an important source of inspiration of the beginning historiography of the computer. This orientation towards the history of mathematics and of science was lost in time, and since the 1990s, history of computing has been mostly oriented towards the history of technology (U.S.). However, this evolution has not yet reached its end and has led to some, quite lively, debates at the heart of the community of computer scientists and historians.

One of the results of this evolution has been that but few historians have tried to study the interactions between mathematics and computing, because of the methodological orientation and because of the mathematical knowledge involved. This special issue wants to be a contribution to such research that tries to bridge this considerable gap in both the historiography of mathematics *and* the historiography of computing.

BIBLIOGRAPHY

BORWEIN (Jonathan), BAILEY (David), 2004, *Mathematics by Experiment: Plausible Reasoning in the 21st Century*, Natick (Mass.), A. K. Peters.

BULLYNCK (Maarten), DE MOL (Liesbeth), DURAND-RICHARD (Marie-José) (eds), 2013, « Report of the Symposium "Mathematics and Machines: Explorations of machine-assisted mathematics since 1800" », in *Report of the sessions of the 24th International Congress on the History of Science, Technology and Medecine,* Manchester 2013, p. 37-42.

CROARKEN (Mary), 1990, *Early Scientific Computing in Britain,* Oxford, Oxford University Press.

GRIER (David A.), 2005, *When Computers Were Human,* Princeton, Princeton University Press.

MINDELL (David A.), 2003, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics,* Baltimore, John Hopkins University Press.

SMALL (James S.), 2001, *The Analogue Alternative: The Electronic Analogue Computer in Britain and the USA, 1930-1975,* London, Routledge.