**Mathematisches Forschungsinstitut Oberwolfach (Germany)**

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# Mathematical Instruments Between Material Artifacts and Ideal Machines: Their Scientific and Social Role Before 1950

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## Abstract


Since 1950 more and more mathematicians are familiar with the digital computer in their professional practice. But before this time a lot of other instruments, mostly forgotten, were also commonly used, both to compute numerical or geometrical objects, to explore mathematical situations, to conjecture new results and to apply mathematics in various scientific contexts. The problem of characterizing the mathematical objects that can be constructed with a given set of instruments gave birth regularly to deep theoretical investigations, since the Euclidean geometry of constructions with straightedge and compass until Shannon's theorem, which, in 1941, stated that the functions constructible with a differential analyzer are exactly the solutions of algebraic differential equations. Beyond these mathematical aspects, instruments are to be considered also as social objects, inscribed in a given time and in a given cultural tradition, and crossing the points of view of the inventor, the maker, the user, and the collector. In this sense, mathematical instruments are an important part of the mathematical cultural heritage. They are widely used in many science museums to show the cultural value of mathematics to the public. This workshop shall bring together mathematicians, historians, philosophers, collection curators and education scholars to confront the various approaches to the history of mathematical instruments, and to compare the definition and role of these instruments over time keeping in mind the following fundamental questions: What is mathematical in a mathematical instrument? What kind of mathematics is involved? What does it mean to embody mathematics in a material artifact? And how do non-mathematicians use this kind of embodied mathematics?


## Description of the aim

What is a mathematical instrument? The main aim of the workshop will be to question and make precise the meaning of this expression before 1950, that is before the appearance of the digital computer. Instruments have been seen in very different ways in different mathematical cultures – that's one of the reasons why we are having trouble now characterizing the situation in a global and definite way. For example, at times certain types of tables were seen as instruments, and not distinguished in terminology from a brass, wooden or paper instrument performing the same function. Referring to two major ancient surveys in this domain, there are deep differences between the definitions and classifications we may find in Nicolas Bion's *Traité de la construction et des principaux usages des instruments de mathématiques* (1709) or in Friedrich Willers's *Mathematische Instrumente* (1926). The changing role and character of mathematical instruments reflects, surely, the changing nature of mathematical disciplines generally, so there is a danger from setting up too narrow a definition of missing some of the big conclusions that might emerge. It will be safer in this respect to allow 'instrument' in the various epochs we will cover to mean what the mathematicians (again perhaps self-defined) took the term to mean. Fortunately similar words are used in the language traditions we are likely to cover (and we can admit terms like 'organon', 'machine', 'device', 'apparatus', etc.).

In the earlier period there are many instruments that perform what we would think of as mathematical operations (and so have had to be designed by people with mathematical skills) but whose professional location and the outcomes they provide might not seem mathematical to us – surveying, navigation, dialing, cartography, artillery, etc. The 'mathematical' operations are not explicit – they (at least from our viewpoint, but perhaps not as seen in the period) are contained within the operation of the instrument. Astronomical instruments, like astrolabes, quadrants, Ptolemy's rulers, or equatoria have been the most common mathematical instruments for a

long period in the Middle Ages. They exploit to a large extent geometrical properties in a clever way to transpose between coordinate systems or metrics. Dividing their scales and accurately adjust them to parameters like latitude or epoch would require considerable mathematical skill. Another example is that of perspective machines, which represent an embodiment of a mathematical theory, even if this was not always perceived by the users of these machines. More generally, mechanical devices like compasses, slide rulers, levers, balances, etc., were largely used by non-mathematicians (until today).

For the historian, one of the main interests of mathematical instruments is that they are at the crossroad of, on the one hand, the making and the use of material artifacts and, on the other hand, the development of abstract concepts, methods and theories. They are involved simultaneously in technology and mathematics (here we think of 'pure' mathematics as well as of 'mixed' or 'applied' mathematics when these distinctions make sense). In the early days, the approach to mathematics was perhaps a more mixed one. From Nicomedes's conchoid tracer to Galileo's sector to Oughtred's circular slide rule, geometry sometimes experimented with using more than just compass and straight edge, and the calculators used sometimes graphical means to get approximations. Up to mechanical calculating machines and differential analyzers, all these tools permitted mathematicians and other scientists to experiment on numbers, curves, functions, solutions of algebraic or differential equations in order to make conjectures and develop new theories. The concrete and clever use of these devices was also closely linked to the creation of numerical and graphical methods of calculation that gave birth to numerical analysis as an autonomous discipline at the beginning of the 20th century. Far from actual calculation and measurement, mathematical instruments could be also thought of as 'ideal' machines: mechanical linkages described by Descartes, tractional integraphs imagined by Leibniz and Vincenzo Riccati were not introduced at first to be manufactured and employed for concrete applications, but conceived for theoretical purposes, as a way of legitimating the use of new curves and new types of constructions in geometry. Thus the situation appears as being complex: the workshop will have to examine in depth the creative and genetic role of instruments in the development of mathematics.

Studying mathematical instruments, the interaction between different group-cultures and different mathematical traditions emerges also inevitably, so our workshop will not neglect a more social approach. It starts from the observation that, at least in the ancient times, the scholarly mathematics was mainly promoted by people with university training, who knew Latin, sometimes Greek, who had also a rhetorical and methodological training in how to think and write, while instrument makers did not have this education. Nevertheless, the makers had access to a mathematical tradition, in part oral in part also written, that allowed them to think often of the same questions and problems as the scholarly people. Speaking of interaction between artifact and theory, this interaction is not necessarily witnessed by one mind, one inventor, one mathematician, only – it means also interaction between people from different groups, between those who materially and technically assemble instruments, and those who make theories on mathematical properties. Instruments are also what their users make them. In the history of technology, which comes sometimes close to that of mathematical instruments, you can write a narrative from the point of view of the makers, but also the point of view of the users. This raises questions like: what do these instruments stand for, how are they designed, discussed, made, promoted, sold, used, explained, taught, represented, advertised, why were they bought, admired, published in so-called theatres, etc.? And of course also where were they collected, displayed, etc.? All these social interactions are what makes mathematical instruments such a particular research object. They are conceived, but also built (where? how? by whom?) and they are used not only by mathematicians. That is to say that we have a large array of actors, and each is interesting to be studied.

A lot of books and papers have already been published on the subject of mathematical instruments but, in our opinion, the major part of these studies has been conducted in too independent and specialized ways by mathematicians, philosophers of science, historians of mathematics, historians of computing, historians of astronomy, historians of technology, historians of engineering, museum conservators, private collectors, and researchers in mathematics education. The novelty of our workshop is to gather scholars from all these communities to work together. For the concrete organization of the meeting, we will try to balance general sessions devoted to defining, characterizing and classifying mathematical instruments at different times – taking into account the points of view of the different actors involved – with specific sessions devoted to certain periods, certain geographical areas, certain parts of mathematics, certain professional milieus, certain types of instruments, or certain social aspects of their intervention. We hope that this will give birth to new insights into this transversal subject and nourish future pertinent investigations.