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Book review

Des Cordes aux Ondelettes L'analyse en temps et en fréquence avant et aprees Joseph Fourier. Un inverseur de l'équation de la chaleur de Fourier: B. Escudié, C. Gazanhes, H. Tachoire and V. Torra

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Recently, a book (in French) which is focussed on Joseph Fourier, the man and his work with a historical survey from the Greek times until now, has been published by the Press of the University of Provence. The book is prefaced by Prof. Bernard Picinbono, member of the Academy of Sciences of Paris. It contains 500 pages, 300 figures and 16 color sheets.

The book is divided into two parts of contains twenty chapters. The first part deals with the time and frequency analysis from the Pythagorean time until now. The Ariadne guide of this part is Acoustics. It ends with current systems analysis (signal processing). The second part of the book is devoted to a partly unsolved issue i.e. conduction calorimetry: an application of the inverse heat transfer Fourier equation.

The first part begins with the description of the slow emergence of the frequency concept and early studies on vibrant strings. It starts with Pythagoras (570–480 BC) who discovered the relationship between the length of the strings and the heights of the sounds. Two thousand years later, Galileo (1564–1642) studied the oscillations of the pendulum. He made clear the concept of frequency and established the vibrant string law (chapter 1). Then, Newton (1642–1727) opened the way to the wave equation that was definitely established in 1747 by d'Alembert. At this time, there was a controversy between d'Alembert, Euler, Bernouilli, Lagrange about the solution of the wave equation through trigonometric series (chapter 2). Joseph Fourier (1768–1830) solved this problem. He established the heat transfer equation and solved it by means of Fourier series (chapter 3). The harmonic analysis was born with Fourier thus leading to signal processing.

At the beginning of the 19th century, scientists and engineers made efforts to set up techniques and instruments furnishing the Fourier coefficients. During the 19th century, mechanical sensors, as the Kelvin tide predictor, were developed and remained in use for the next hundred years (chapter 4 and 5). Simultaneously, application in acoustics was developed as the Edison phonograph and the Berliner gramophone. At this time, too, following his analytical studies of the audition, Helmholtz (1821–1894) starts the model for the auditory reception via a battery of resonators. In 1872 Rudolf Koenig built the first sensor (allowing to detect the speech signal). The Koenig device depicts the beginning of spectral analysis and constituted the first approach of time and frequency analysis (chapter 6). In 1880, the first studies on the location of sound sources were started, mostly for military purposes and submarine identification (chapter 7). The process constitutes the

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basis of the present acoustic imaging and radioastronomy. At the end of the 19^{th} century. André Blondel (1863–1938) designed a new technique of analysis based on resonant electric circuits with ‘ultra fast’ galvanometers. Later, electronic instruments replaced the Blondel devices (chapter 8).

The next chapters of the book deal with the transition from mechanical to electronic techniques. This evolution coincided with the beginning of radioelectricity and analogic electronics (chapter 9). Taking advantage of the invention of the triode, of the heterodyne detection and of the oscilloscope, several types of devices were developed (chapter 10) and correlation functions were established in particular for acoustic imaging (chapter 11). The first sensors in time and frequency were built around 1945 (chapter 12). About fifteen years later, digital computers were developed for general purposes. Finally, the first part of the book describes the transition from hybrid techniques to time and frequency analysis by purely digital devices (chapter 13). Since 1965, the Fast Fourier Transform has extended the field of application of spectral analysis (chapter 14). Chapter 15 describes the atomic decomposition according to Denis Gabor, time and frequency analysis (Wigner–Ville) and wavelet analysis (Morlet, Grossmann and Meyer).

The crucial contribution of Fourier who provided the tools for calculating temperature profiles and for analyzing periodic phenomena is emphasized. Equations of heat transfer have allowed to solve the classic problem of the determination of temperature distribution and its evolution with time. The Fourier formalism further allowed to evaluate thermal properties of materials (thermal diffusion and conductivity). It also enabled to solve the reverse problem: the determination of the thermogenesis of a phenomenon from temperature-time data.

The second part of the book deals with the above issue. Conduction calorimeters represent an input-output system centered on the determination of thermogenesis from thermal out signal. The Laplace transform and Fourier heat transfer equation constitute the basis of the current formalism of thermogenesis analysis.

Chapter 16 summarizes the history of thermal methods and instruments from the Lavoisier and Laplace ice calorimeter (1780) to the adiabatic system of Richards (1905). All these devices have allowed to discover or to check some of the fundamental laws of thermodynamics. Around 1920, Albert Tian built the first conduction calorimeter in view to study slow and low power reactions. However direct reading of the instrument output did not yield a precise picture of the actual thermogenesis of the phenomenon. Tian established a first order model accounting for the thermogenesis based on graphic filtering of the curves (chapter 17).

Around 1950, Edouard Calvet transforms the Tian device. The differential Tian–Calvet microcalorimeter is at the origin of the modern calorimetric devices presently used in most laboratories. Calvet introduces more sophisticated filters. As Tian, he was interested in studying the dynamic aspects of the phenomena. In chapter 18, some new devices are described. Heat transfer equations connecting the input and output signals are also presented. Overcoming the technical difficulties, these equations allow more accurate evaluation of the thermogenesis from the curves.

In 1965, the first International Conference on Microcalorimetry chaired by Calvet was held in Marseilles. Signal processing was one of the major topics of the Conference. During the forthcoming twenty years, the development of appropriate deconvolution methods remained a constant subject of interest. Chapter 19 describes the digital methods used for the identification of the calorimetric systems and for the deconvolution of the curves. In this part, the basic formalisms related to conduction calorimeters are included. The last chapter presents some examples showing that the application of these methods converts the conduction calorimeter in a thermal oscilloscope. These examples concern some calorimetric and thermal analysis applications. For instance, thermodynamics of solutions, liquid mixtures and phase transition in solids, in particular in shape-memory alloys.

The book is essentially devoted at those who are interested in the history of Science and, in particular, in the treatment of the signal processing and, also, in systems of thermal measurements. It can also be useful for a series of lectures at the university level. In particular, some classic problems in the Science evolution can be extracted and emphasized. For instance, the substantial language differences in the concept representation or in the communication difficulties, the mathematical discussions related to function properties and their representation by a series of trigonometric functions, the discontinuous steps in science development frequently related to instrumental 'discontinuous' evolution inducing new basis for increased knowledge. Other subjects can be considered peculiar creating interesting discussions in the classroom. For instance, the homework (or the 'internet use' in the old part of the 20^{th} century) established by Blondel. Other aspects can be emphasized as the parallel evolution of experimental devices; i.e. the flame analyzer and the Edison cylinder, the acoustic wall detectors and the radar, the level of apparent computing support in real calorimeters and the origin of the systematic errors, etc...

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