Measurement and Probability: A Probabilistic Theory of Measurement with Applications
Giovanni Battista Rossi
Springer, New York NY, (2014),
286 pp., hardbound, 129 USD,
ISBN 978-94-017-8824-3

The book is addressed to specialists who deal with measurements in engineering work, metrology and scientific research. The chapter with some applications to acoustical measurements might be of special interest for acousticians and for those who calibrate acoustical instrumentation. The text is structured in three parts with a total of 12 chapters which present the theory of measurement with related applications.

The first part of the book is formed of two chapters which present general aspects on measurability and measurement uncertainty.

Chapter 1 discusses about measurability starting from basic thoughts on counting and measuring. The text defines essential concepts like measurable property, measurement value, fundamental and derived quantities, as needed to describe the physical and psychophysical measurements. The measurement scales and the characteristics of a measuring process and measuring system are then discussed.

Chapter 2 gives a general view on measurement uncertainty. A brief historical background shows the main stages in the evolution of this domain, from the early theory of errors developed by Gauss and Laplace to modern problems like the uncertainty relations in quantum mechanics. The author presents the probabilistic approach used in the book that enables the uncertainty to be uniformly treated in all its forms related to measurement scale, empirical relations, measurement process and measuring system.

The second part of the book is formed of five chapters which present the theory of measurement in a deterministic frame and in a probabilistic approach, followed by aspects related to the measurement process, inference in measurement and multidimensional measurement.

Chapter 3 focuses on the theory of the measurement scale in a deterministic framework starting from the meaning of measurement. After introducing primitive concepts like object, property, empirical relation, empirical system and observable output, the book develops the theory of the fundamental scales (ordinal, interval and ratio) and derived scales. The discussion is completed with aspects on systems of quantities and on The International System of Metrology.

Chapter 4 presents the theory of the measurement scale in a probabilistic approach. After a brief review on theory of probabilities, the author introduces the probabilistic representations for the order, interval, intensive and extensive structures and develops the probabilistic theory of the fundamental scales and derived scales.

Chapter 5 describes the measurement process first in a deterministic model and then in a probabilistic model justified by the uncertainty of any measurement. The latter approach leads to a probability space for the measurement process which is rigorously developed by author in terms of discrete probabilistic variables. The analysis is then extended to continuous probabilistic variables.

Chapter 6 deals with the inference in measurement. The text highlights the importance of learning from data for keeping the uncertainty under control when developing models and making inferences in measurements. From simple and instructive examples, the reader learns how to infer in probabilistic models by using hypothetical-deductive and inductive ways for making correct decisions when accepting or rejecting data from measurements. The author shows that all these ways should be used in a measurement evaluation and verification.

Chapter 7 extends to the multidimensional measurements the theory developed before. After outlining changes needed for a two-dimension measurement and giving a brief review of math of distances and metrics, the author develops rigorously the theory of nominal and distance structures and the probabilistic representation of such structures for a multidimensional measurement.

The third part of the book is formed of five chapters which reveal applications of the theory to the perceptual measurements, uncertainty evaluation, inter-comparisons and calibrations.

Chapter 8 is dedicated to perceptual measurements, with a selection of applications from acoustics. The reader is introduced in the domain of psychophysical measurements through concrete steps and topics from this domain: defining the acoustic quantities, the loudness of pure tones and of the pink noise, and then measuring the loudness. Along with the master scaling approach previously known from literature for the loudness measurement, the author presents a robust magnitude estimation method which was recently developed in his laboratory.

Chapter 9 discusses an important and often challenging part of a measurement process: the evaluation of measurement uncertainty. The discussion goes from how to develop a mathematical model of the measurement process, through an application to the linear models used for the uncertainty calculations. The author shows how to deal with the systematic effects and random variations when estimating the measurement

uncertainty and gives an example of analysis for the low-resolution measurements. Other topics discussed here are hysteresis phenomena in modeling of the measurement process, uncertainty evaluation in the case of indirect measurements, actually available measurement software packages and an example of uncertainty evaluation utilized in the GUM (Guide to the Expression of Uncertainty in Measurement Bureau International des Poids et Mesures).

Chapter 10 brings into discussion the importance of inter-comparisons and calibration for a worldwide quality assurance system for measurement. The author gives an overview on such system at the national and international levels and then addresses the role of the inter-lab comparisons and calibration. An example shows, in a probabilistic framework for comparisons, how to evaluate the individual results from the measurements on a traveling standard. Similarly the calibration process is described, as a key tool in the overall system of metrology and measurement.

Chapter 11 deals with the measurement-based decisions. The author describes the inferential process for conformance assessment and builds a probabilistic approach with examples for the risk analysis. The reader learns about a software package developed for risk analysis applications and about the legal metrology.

Chapter 12 introduces the reader in the domain of dynamic measurements, where the quantities to be measured have some variation in time. The author shows how to develop a probabilistic framework for a direct dynamic measurement like the measurement of a cosine signal, and for an indirect dynamic measurement like a spectrum measurement.

The text challenges the reader through the rigorous math used in the theory of measurement. A typo is seen in equations (5.51) and (5.52) where the working interval should be written $(x_i \pm x_r/2)$ rather than $(x_i \pm x_r)$. However this typo does not affect the reader understanding of the presented topic. Through the whole content, with numerous references in each chapter, the book of Giovanni Battista Rossi is a very valuable text, recommended to all those who are connected to the theory and practice of measurements.

Valentin Buzduga
Scantek Inc., Columbia MD USA,
v.buzduga@scantekinc.com