The Technology of Binaural Understanding

Jens Blauert and Jonas Braasch (Eds.)
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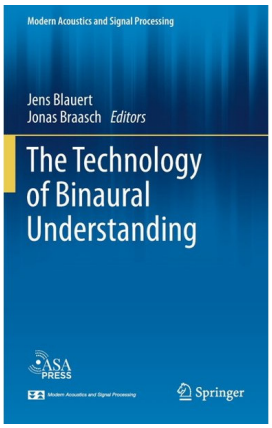

In this important book, Jens Blauert and Jonas Braasch have assembled a fine collection of 25 essays covering many aspects of binaural understanding. Each chapter is authored by specialists in the topic and each contains a detailed summary of its topic, together with a very extensive list of references.

The 25 chapters are arranged in five main sections. Here I use the section classifications and some wording used by the editors. The first section of the book, **"Forming and Interpreting Aural Objects"** deals with psychophysical and physiological effects of hearing as well as related models. The second part, **"Configuring and Understanding Aural Space"**, deals with how humans understand complicated three-dimensional environments. The third part **"Processing Cross-Modal Inference"** highlights how humans integrate auditory cues with cues from other senses to help localize and form perceptual objects. The fourth part, **"Evaluating Aural-scene Quality and Speech Understanding"**, focuses on object-forming aspects of binaural listening and understanding. The fifth part **"Application of Cognitive Mechanisms to Audio Technology"** highlights how humans use cognitive mechanisms to create spatial auditory illusions using binaural technologies. It also discusses how these can be used to create interactive robots. The book concludes with the application of cognitive binaural technologies to the next generation of hearing aids.

The emphasis of this book is on binaural understanding rather than just binaural hearing. As the editors argue, people do not react directly to what they hear but rather they react to what they hear means to them. The editors have published extensively both jointly and as separate authors in books, book chapters, refereed journal articles and conference papers. In an earlier book, The Technology of Binaural Listening, J. Blauert (ed.) Springer and ASA Press, 2013, the focus was on sub-cortical functions of the auditory system; that is the functioning of the system prior to the processing that takes place in the human cortex. It is the sub-cortical parts of the auditory system that are responsible for the pre-processing of auditory signals; while it is the cortical parts of the auditory system that are responsible for higher level functions such as recognition of sounds including speech, classification and localization of sounds, scene analysis, assignment of meaning, quality assessment and action planning.

Each chapter in this book is self-contained. Each one begins with an abstract summarizing the contents of the chapter. Then each has a lengthy introduction discussing previous relevant studies and finally it includes a conclusion section with extensive references. Although the book is written mostly for specialists, the non-specialist reader can learn a lot by dipping into different chapters. I looked at a few chapters in some detail. I was never disappointed, always learning something new and interesting.

I chose to look at the first chapter Reflexive and Reflective Auditory Feedback by Blauert and Brown. This chapter introduces important concepts and sets the stage for discussions in succeeding chapters. Many earlier studies have considered the auditory system in isolation. But here the authors reject that approach. The system is part of a much more complex system, the human body. It is not an isolated system, but instead is integrated in a complex structure of nerve pathways, not only afferent (ascending) pathways to the cortex, but efferent (descending) pathways down to the two cochleae and the two chains of auditory ossicles in the middle ears. Not only this, but there are also nerve pathways between the two auditory systems and there are numerous feedback loops as well. The cortex is constantly involved in the whole auditory process.

Another topic is the perceptual 3-D formation of auditory space and how the system uses this to localize source(s) of sound. This is important when the sound could be a warning of danger and a decision needs to be made rapidly if the source is in front of or behind the head. Two chapters deal with this in detail, Formation of Three-Dimensional Auditory Space by Majdak, Baumgartner and Jenny and Biological Aspects of Perceptual Space Formation by Pecka, Leibold and Grothe.

An important use of the technology discussed in this book is the design of robots, which can go where it is hazardous for humans. The design of robots is discussed first in the chapter by Blauert and Brown. They describe a robot capable of binaural listening with the capability not only to perceive, but also to interpret and understand the environment. A combination of signal-driven and hypothesis-driven algorithms is used in its design. The auditory system includes a pair of internally-mounted microphones. To include visual inputs, a stereoscopic pair of cameras is used to simulate human binocular vision. Later in the book, in a chapter authored by Cohen-Lhyver, Argentieri and Gas, robot design is discussed again. The authors describe the modulation of the robot's head movements.

Three chapters deal with auditory effects of sound in concert halls, room effects on source localization and on musical performance, Auditory Spatial Impression in Concert Halls by Lokki and Pätynen, Auditory Room Learning and Adaptation

to Sound Reflections by Seeber and Clapp and Room Effect on Musicians' Performance by Kob, Garí and Kalkandjiev. The first chapter discusses the importance of evaluating the acoustics of concert halls from the perspective of binaural hearing. They argue that the early reflections are of paramount importance; concert hall acoustics can change the audience's perception of a performance. The authors describe their experiments simulating the acoustics of a concert hall using 33 loudspeakers on the stage and 24 measurement channels. The room impulse response for each channel was determined using a 3D vector intensity probe.

Seeber and Clapp, the authors of the second chapter, discuss how the human auditory system can still function effectively in adverse acoustical situations. It is well known that typical human listeners are quite able to localize the source of a sound even in the absence of other sensory cues. The auditory mechanism for this is known as the "precedence effect", which has been studied widely by researchers using a single loudspeaker as the source and a loudspeaker with a delayed signal as the reflection. In such cases, the source signal is received first, followed by sounds from surfaces providing multiple reflections. The authors describe a series of experiments to simulate this situation in which both a single source signal and a single reflected signal are presented. The delay in the arrival of the reflected signal was varied from less than 2 ms up to about 24 ms. For short delays up to 12 ms, a single fused sound location is reported. For delays less than 2 ms, the source is reported to be located between the two loudspeakers with the phenomenon termed the "summing location". For longer delays of 12 – 24 ms or more, the sound is reported as coming from two distinct locations, the first at the source and the second at the reflection location. This phenomenon is known as the "precedence effect."

In the third chapter, Kob, Garí and Kalkandjiev describe experiments with musical instruments including pianos, violins and trumpets. In order to understand how room acoustics affects performance and to model the interaction of the performers with room acoustics, it is necessary to make measurements. This necessitates defining the key aspects of music performance and selecting the aspects that are needed to describe them. Such laboratory measurements were often performed on pianos. Of considerable importance facilitating measurements was the introduction of the Music Instruments Digital Interface (MIDI) standard for a digital protocol which provides immediate availability of digital data describing basic musical events.

Automatic speech recognition (ASR) is now widely used by airlines, insurance companies, banks, and so on, to guide customers' initial inquiries to a responsible human. With further development it is expected that ASR will enable natural voice interaction between humans and intelligent machines. In their chapter Binaural Technology for Machine Speech Recognition and Understanding, Stern and Menon describe and compare ways in which the accuracy of automatic speech recognition can be improved using signal processing techniques based on binaural perception and technology. The authors demonstrate that algorithms that use binaural information can produce considerably improved speech recognition in noisy and reverberant environments. A last section features two related chapters, Intelligent Hearing Instruments—Trends and Challenges by Georganti, Courtois, Derleth and Launer, and Scene-Aware Dynamic-Range Compression in Hearing Aids by May, Kowalewski and Dau. The first summarizes hearing instruments currently available to assist those with hearing loss. These include hearing aids, cochlear implants, middle-ear implants, bone-anchored hearing systems, and auditory brainstem implants. The second, by May and colleagues, also discusses the design of hearing aids and the necessity of using wide dynamic range compression to improve audibility while at the same time providing acceptable loudness at high sound pressure levels. While fast acting compression with short release times allows sufficient amplification of low-level speech sounds, it can also amplify noise in the speech gaps.

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Engineering Acoustics — Noise and Vibration Control

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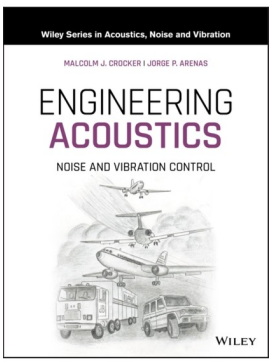

This new book, a member of Wiley's "Series in Acoustics, Noise, and Vibration", provides comprehensive coverage of noise and vibration control in the context of engineering acoustics. It aims at all kind of readers with an interest in this field, be it educators, students, consultants, practitioners, or even politicians.

The volume features two distinct parts. While the first one (Chapters 1–9) offers an introduction to relevant theoretical foundations, the second one (Chapters 10–16) presents and discusses a rich variety of application examples which the authors, based on their extensive experience, have identified as particularly important. As the authors are both experienced academic teachers and acoustical consultants, all material is carefully selected and clearly presented.

The nine theoretical chapters are properly useable as a basis for educational courses as well as for self-study. Numerous exercise problems and their solutions support this purpose. Mathematical background knowledge on the undergraduate level will facilitate their comprehension, but the book at large offers a lot of useful information also to those readers who do not dispose of it. By the way, as is often the usage in practice, mathematical formulas are written as numerical equations and not as quantity equations in this book. Note that this requires values to be inserted in the prescribed units.

The theoretical part deals with the following physical items, among many others: Free and forced vibration of lumped-element vibrators and of continuous mechanical systems, such as beams and plates. Further, the book covers plane and spherical sound waves, their generation and propagation, sound intensity, sound power, reflection, scattering, diffraction, ray acoustics, and reverberation.

Besides the physical aspects of sound, basic physiological and psychoacoustic ones relevant to noise control are addressed, for example, the anatomy of the ear and the vocal tract, speech production, critical bands, loudness, pitch, and masking. Sound localization and auditory scene analysis are not mentioned. Of course, even a book of nearly 800 pages cannot include everything. Yet, a significant discussion is devoted to the effects of noise and vibration on people and to criteria for assessing human responses to these effects.

Further themes within the theoretical part that are of particular importance are equipment and tools for the measurement and analysis of noise and vibration quantities, among others, sound intensity, sound power, and transmission loss. Hereby, a general strength of the book becomes to the fore, namely, the rich illustration that also includes sketches and photographs of practical setups. This feature is very helpful, for example, regarding sound-intensity measurement, where many acousticians may need some brush-up to the current state of technology.

For noise control, it is of paramount importance to tackle noise reduction as a system problem where priorities have to be set based on aspects like effectiveness, feasibility, and cost. The available elements for this procedure are extensively dealt with in the book.

The eleven application-oriented chapters are characterized by not only identifying specific noise-and-vibration problems, but also offering detailed engineering solutions to them. For instance, in the chapter on silencers, basic construction principles are illustrated and explained based on the underlying theories, but also examples and data are provided to enable readers to specify custom-built silencers by themselves. This approach also holds for most of the other application areas dealt with in this book.

These further areas include noise and vibration of machines, surface transportation (automobiles and railroad systems), air-conditioning systems and other building infrastructure. The book also covers noise control for aircraft and airports, and community noise.

To mention a particular highlight, Chapter 12 contains an introduction to the method of statistical energy analysis (SEA), a powerful tool that is still not widely adopted by acoustical consultants.

Currently, the art and practice of sound-and-vibrations control more and more tend to include perceptual, cognitive, and social aspects. In the current book, this tendency is only briefly mentioned as some places, for instance, under the topic of soundscapes. However, measuring and assessment methods to this end are not dealt with. Nevertheless, readers are advised to carefully monitor the development in these areas as they will increasingly shape noise-and-vibration-control activities of the future.

Last but not least, it is worth mentioning that each book chapter contains a rich list of references to the relevant literature. The book is completed by a glossary of noise-and-vibration-specific terms and an elaborate index.

This reviewer is happy to have the book on his shelf as a general reference work. He recommends it to all students, engineers, consultants, and decision makers, who are faced with noise-and-vibration-control tasks.

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