Speech Processing and Synthesis Toolboxes

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BOOK REVIEWS

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Fundamentals of Noise and Vibration

F. Fahy and J. Walker

E & FN Spon, London and New York, 1998.
xvii+ 518 pp. Price: $60.00.

According to the preface for this text, it ''...is based on material presented during the first semester of the postgraduate Masters Course in Sound and Vibration Studies at the Institute of Sound and Vibration Research in the University of Southampton, UK.'' At 518 pages and with a significant breadth of coverage, that first semester must be rather challenging. Nonetheless, having read this text at length, I intend to hand it to my own students with the simple directive, ''Read this.'' Paraphrasing the preface, the first semester of the ISVR Masters Course targets students with little or no prior knowledge of acoustics. Many of us find ourselves in the same situation when introducing new students to acoustics here in the U.S., and it is that application that this text serves most admirably.

The text is organized into eight chapters, with relevant references and questions at the end of most chapters. Each chapter has a different author, whose expertise and experience is appropriate to the subject matter of the chapter. Chapter 1, authored by Phil Nelson, is entitled ''An introduction to acoustics.'' The chapter introduces, in brief, many of the basic concepts in acoustics, including the wave equation, impedance, standing waves, point sources, etc. The material is presented clearly and logically, pitched at a level appropriate to students new to the field. This single chapter has a breadth comparable to some two-semester graduate courses, but without the depth. The depth is intentionally omitted here (and in subsequent chapters), yet its absence is not a flaw in the text's purpose: to support introductory studies in acoustics. Nelson includes references to a number of excellent texts where the full measure of material may be found, including Kinsler and Frey, Skudrzyk, and Pierce.

Chapter 2, authored by N. Lalor, is entitled ''Fundamentals of vibration.'' The chapter presents a straightforward development of vibration-related concepts up through two-degree-of-freedom systems. It addresses free and forced response, damped systems, transmissibility, forced excitation, isolation, etc. In addition, there is a brief development of Lagrange's equations at the end of the chapter. A weakness of this chapter is the complete lack of references to other texts with more extensive development of the theory of vibrations.

Chapter 3, authored by I. H. Flindell, is entitled ''Fundamentals of human response to sound.'' The chapter provides an excellent review of the impact of sound on humans, including such issues as annoyance, sleep disturbance, and activity interference. The chapter also addresses the physiology of the hearing mechanism, and human hearing characteristics such as masking, level dependency, etc. The chapter also addresses various measurement schemes for acoustic signals, including some limited discussion of FFT analyzers. As a minor quibble with the sequence of information within the text, frequency analysis is not introduced until Chap. 6, and as there is nothing in this section to direct the reader to Chap. 6 for more detail, the FFT material here seems a bit out of place. (I would have preferred the chapter on frequency analysis to have immediately followed Chap. 2.)

Chapter 4, authored by M. J. Griffin, is entitled ''Fundamentals of human responses to vibration.'' This material is frequently absent from other introductory acoustics texts, and even from most texts on vibrations, so its inclusion here represents a unique resource. The chapter covers measurement systems, health impacts, and recommended practices for human exposure to vibration. As one might imagine from a text originating in the UK, many of the impact studies and standards that are referenced in this chapter (and in the other chapters) are of British or European origin. This does make some of the material of less relevance to U.S. readers and practitioners, but not unduly so.

Chapter 5, authored by F. J. Fahy, is entitled ''Fundamentals of noise and vibration control.'' The chapter begins with a brief review of some basic acoustics terminology (duplicating material found elsewhere), and then moves into a quite thorough and valuable exposition on the nature and characterization of noise sources. The preliminaries out of the way, the chapter then proceeds to review general concepts in passive noise control, including source–path–receiver considerations. The chapter then presents specific theory on sound absorption, transmission through partitions, and barriers. The chapter concludes with a brief review of vibration control concepts. On the whole, the chapter is a good introduction to the fundamental concepts and a few of the more commonly encountered theoretical matters. The references direct the readers to more comprehensive treatises on noise control.

Chapter 6, authored by J. K. Hammond, is entitled ''Fundamentals of signal processing.'' The chapter presents a broad overview of the theoretical basis for digital signal processing. It concisely covers many of the topics that first-time students find so confounding (or of which they are blissfully ignorant) when using the now ubiquitous FFT signal analyzers, whether dedicated or PC based. Such topics include sampling effects and windowing, and application of various statistical measures. The chapter also presents the topic of system identification. My sole issue with this chapter is one of sequence: given that other preceding chapters had reason to resort to discussions of frequency analysis and analyzers, this chapter more logically should have followed the second chapter.

Chapter 7, authored by T. G. Leighton, is entitled ''Fundamentals of underwater acoustics.'' The chapter opens with a broad discussion of matters related to sound propagation in the oceans, including sound speed profiles, influence of bubbles, and ray acoustics. The chapter then discusses a variety of nonlinear effects in underwater acoustics, including finite-amplitude propagation, self-effects, and parametric arrays. The chapter concludes with a brief discussion of the medical effects of ultrasound. While oddly juxtaposed with a chapter that otherwise deals with sound propagation in the oceans, the inclusion of the ultrasound material here is probably due to ISVR's program in medical acoustics.

Chapter 8, authored by R. J. Pinnington, is entitled ''Fundamental principles of measurements and analysis techniques.'' This chapter is a fitting conclusion to the text, as it presents the issues and theory related to the measurement of acoustic and vibration signals, the topics of the previous chapters. For novice students in experimental programs, this chapter will be quite an eye-opener as it describes the interactions between exciter and test articles and frequency limitations of devices. The chapter concludes with a very brief discussion of practical issues in measurement, such as noise, cross-talk, and digitization effects. However, the utility of this concluding section is limited by its brevity and its lack of references to more detailed expositions on these very important issues.

Overall, the text is well organized and presented. Most chapters have good references and some sample problems. A solutions manual is available. The depth of the material in each chapter is admittedly limited, yet its

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absence is not a flaw in the text's purpose: to support introductory studies in acoustics. The preface states that a companion volume based on the second semester course at ISVR, as well as their Advanced Course in Noise and Vibration will follow: I look forward to reading that text, as well.

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The Boundary Element Method in Acoustics

Stephen Kirkup

Integrated Sound Software, West Yorkshire, UK, 1998.
xii+135 pp. Price: $63.00 (Core Package: Book and ABEM2D disk) and $499 (Development Package: Book and ABEMFULL CD).

The subject of the boundary element method (BEM) in acoustics has been discussed by so many people over the past decade that it no longer draws any excitement or attention to me. I have collected at least one book (Ciskowski and Brebbia, 1991) that bears the same title as the current one. So my first reaction to the request of review was why another book on BEM? It turned out that this book is concerned with the implementation of BEM using FORTRAN 77 for acoustic radiation and scattering in both interior and exterior regions. The computer program is known as Integrated Sound Software (ISS), and the BEM codes are written in the simplest forms to allow for flexibility in engineering applications. Specifically, the boundaries are approximated by straight lines for two-dimensional problems, planar triangles for three-dimensional problems, and truncated cones for axisymmetric three-dimensional problems. The functions are approximated by constants or C^0 interpolation on the boundary elements. The non-uniqueness difficulties inherent in the Helmholtz integral theory for the exterior region are overcome by Burton and Miller's method (1971). Tests on various subroutines and the corresponding results are demonstrated in Chaps. 4, 5, and 6 for interior and exterior acoustic problems, and interior modal analysis, respectively.

Overall this book serves as an extended user manual for the BEM codes to solve acoustic radiation and scattering problems in interior and exterior regions, with a brief discussion of the Helmholtz integral theory and listing of formulations for different situations. As such it seems balanced. However, I have the following comments on the subject matter.

(1) While the integral on the right side of (3.37) is finite, the first two terms are not in the limit as $q \to p$. Detailed justifications must be given in order for this general relationship to hold. My guess is that (3.37) holds simply because a planar boundary element is used.
(2) It is not clear how the singularities are handled as the field point approaches the surface in this book. Figure 3.1 shows a diagram in which the planar triangle element is divided into three parts when $p \in \Delta\tilde{\Gamma}$. However, exactly how this division will circumvent the singularity is not discussed.
(3) Discussions on scattering in an interior region on p. 60 are meaningless. Unlike scattering in an exterior region, the incident wave in an interior region is not well defined because of the presence of reflected waves. Hence it is inappropriate to copy the treatments of scattering for an exterior region to an interior region.
(4) The field solution inside a sphere of unit radius should not be $\varphi(p) = e^{ikr}/r$ (see p. 75), because it is unbounded when $r=0$. Justifications are needed here.

The computer codes discussed in this book were also examined, which was done as a part of class projects for ME7460: Advanced Acoustic Radiation that I taught at Mechanical Engineering Department of Wayne State University during the Winter semester, 2000. The main topics covered in this course included the Helmholtz integral theory and its implementation using BEM, and near-field acoustic holography. The enrollment of this class was comprised of three Ph.D. and eight MS students. The students taking this course were all very highly motivated and hard working. One of the projects was to use ISS and SYSNOISE® (another commercial software developed by Leuven Measurement Systems) to simulate acoustic radiation from a dilating sphere, an oscillating sphere, and an arbitrarily shaped object. The integral theory and its numerical implementation were discussed at length in class. The students were required to learn ISS and SYSNOISE to solve problems on their own. At the end of the semester, students were asked to fill out surveys of the book and software ISS, which consisted of ten questions. The first five questions were about the clarity of the book. Question 6 was a self-assessment of learning ISS. Question 7 was concerned with the interface of ISS with other software in generating boundary elements and meshes. The last three questions were concerned with the students' recommendation and

TABLE I. Responses to questions 1–8.

No.	Questions	Absolutely	Moderately	Very little	Not at all
1	Have you read the book entitled *The Boundary Element Method in Acoustics*?	36%	64%	0%	0%
2	Do you feel that this book has adequately described the Helmholtz integral theory?	18%	64%	9%	9%
3	Do you feel that this book has adequately described the boundary element method?	36%	46%	18%	0%
4	Do you feel that this book has adequately explained how to run the Integrated Sound Software?	9%	37%	27%	27%
5	Do you feel this book has provided enough examples for you to understand the software for different cases?	18%	18%	37%	27%
6	Do you feel that you can learn how to run Integrated Sound Software on your own?	27%	18%	45%	10%
7	Do you feel that the interface of Integrated Sound Software is straightforward and user-friendly?	0%	0%	18%	82%
8	Would you recommend Integrated Sound Software to your friends?	27%	18%	37%	18%

TABLE II. Responses to questions 9 and 10.

No.	Questions	Excellent	Very good	Good	Fair	Poor
9	How would you rate the book?	9%	9%	36%	18%	28%
10	How would you rate the Integrated Sound Software?	0%	36%	10%	27%	27%

their ratings of the book and software. The results of this survey are shown in Tables I and II.

Most of the responses to the questions were mixed. The overall feeling for the software was not very encouraging, however. The biggest problem with ISS was its interface with other software in generating the boundary elements or meshes. Every student complained bitterly about the interface of this software. On the other hand, the core program can produce relatively good results, even though constant values or a C^0 interpolation scheme is used to approximate the functions on the boundary surface.

Based on the students' feedback and my personal review, I must conclude that this book falls short of providing general BEM codes that can be handy for people working in the field of acoustic radiation and scattering. I strongly recommend that the author consider adding a component that may make the interface of ISS with other software easier in generating boundary element meshes, thus making ISS more accessible to users.

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Comparative Hearing: Insects

Ronald R. Hoy, Arthur N. Popper, and Richard R. Fay, eds.

Springer-Verlag, New York, 1998.
341 pp. Price: $89.95 (hardcover) ISBN: 0387946829.

This is the tenth in the series of the Springer Handbook of Auditory Research edited by Fay and Popper. The lead editor for this volume is Dr. Hoy, a well-known neurobiologist in insect acoustics. In addition to Dr. Hoy, seven other acknowledged experts have contributed to this interesting book.

In the introductory chapter by Hoy, ''Acute as a Bug's Ear: An Informal Discussion of Hearing in Insects,'' it is indicated that the emphasis throughout the book is on tympanal hearing of airborne sound pressure. This limits the scope of the book. Aquatic insects are of course excluded. A more important omission (except for a few brief comments in Chapter 2 and elsewhere) is the group of insects that sense the particle velocity of sound with hair sensilla or antennae in the near field. The emphasis in the book is thus on sensing in the far field. Dr. Hoy provides a readily understood introduction to the tympanal hearing systems of insects. It is indicated that all insects, including the praying mantis, have two ears. In contrast to the ears of vertebrates that are located in the cranium, ears can be found nearly anywhere on an insect's body. How and why this happens is clearly explained. Some details of insect hearing are mentioned briefly, including the fact that insects can be quite sensitive to the direction of a sound source. Directional hearing is a recurring theme in the book. Also, the relatively short life span of insects makes it easier to investigate the evolution of insect hearing.

The second chapter, ''Biophysics of Sound Localization in Insects'' by Michelsen, provides a summary of basic principles, including a listing of three mechanisms of acoustic reception: pressure receivers, pressure-difference receivers, and particle-motion detectors. Pressure-difference receivers and particle-motion detectors are inherently directional. However, the distinction between the two is not clear-cut because pressure-difference receivers can be used to measure particle motion. Directional hearing is required by insects, principally to avoid predators and for mating. The directional hearing of humans and other vertebrates can be explained on the basis of diffraction around the cranial structure and distance between the ears. In a similar way, diffraction and distance between the ears on the thorax of night-flying moths can be used to determine the direction of the ultrasonic signals of bats. In general, however, insects are too small relative to wavelengths of interest to be able to use diffraction and distance between the ears. Thus insect ears generally cannot be considered to function purely as pressure receivers. To obtain directionality, the tympanal structure of the ear has to act as a kind of pressure-difference receiver with pressure exerted by the external sound field on the outside and, on the inside, pressure conveyed through tracheal passages or other air-filled tubes, responding to input from the other ear. This explanation has been worked out in detail for a few crickets and certain grasshoppers. Unlike Hoy, Michelsen states that the praying mantis has only one ear.

In Chapter 3, ''The Sensory Ecology of Acoustic Communication in Insects,'' Roemer is concerned with natural effects that attenuate the transmission of insect signals in the far field, such as absorption in the atmosphere, scattering by vegetation and atmospheric turbulence, the effect of temperature and humidity gradients, and transmission over the ground. These can cause significant frequency-dependent losses in signal strength. To counter such effects, insects have developed ingenious methods of improving acoustic communication, such as the mole cricket amplifying its signals by matching the dimensions of its burrow to the frequency of its call and the South African tree cricket using a leaf as an acoustic baffle. Another obvious method is the redundancy of repetitious, broadband, stereotyped signals. In ways such as these, insects can extend the range and improve the detection of signals to a remarkable degree.

Boyan in Chapter 4 discusses the development of tympanic auditory systems in insects. This is illustrated for three insect groups: grasshoppers, bushcrickets (katydids), and crickets. Section 4 of Chapter 1 identifies these insects and their hearing systems. Development of the auditory system is traced through the embryonic and post-embryonic stages. Only at the adult stage is the insect ear fully functional. Information about the development of the auditory system is also provided by regeneration experiments in which certain parts of the ear can grow again after being removed. The studies described in this chapter provide important clues about how insect ears evolved.

In Chapter 5 Pollack discusses the neural processing of acoustic signals by insects. The first sections summarize the characteristics of sound signals most apparent to insects and subsequent sections describe how these features are detected and analyzed by the nervous system. The material relates principally to the three insect groups used as examples in Chapter 4.

In Chapter 6, ''The Evolutionary Innovation of Tympanal Hearing in Diptera,'' Robert and Hoy consider the directional hearing of a parasitoid fly that is much smaller than its cricket host. A pregnant ormiine fly deposits a few first-instar larvae on or around a field cricket which then enter the cricket by themselves. After about a week, third-instar larvae emerge from the cricket and pupate outside. It is known that the fly detects the cricket host by homing in on the cricket's song and for this purpose it is endowed with keen directional hearing. The song, of course, is not meant for the parasitoid fly but for other field crickets. Because of its much smaller size, the fly's directional hearing has to be different from a cricket. It is this novel hearing capability that is the subject of the chapter. Essentially the very small differences in the time of arrival of the acoustic signals at the two auditory tympana of the fly are mechanically amplified by viscoelastic coupling. Neural processing then provides additional amplification needed for good directional hearing. This work is important because it provides fresh insights into the evolution of directional hearing in insects.

In Chapter 7, ''The Vibrational Sense of Spiders,'' Barth discusses substrate transmission of acoustic signals. It might be asked why the book has a chapter on spiders when there are known examples of insects using substrate transmission. The biomechanics of the transmission process is the same for both, however. As well as discussing transmission paths that can apply to insects, for example in the leaves and stems of plants, Barth provides an interesting discussion of transmission across webs and water surfaces. Spiders are important because they combine, to a high degree, detection of substrate vibration with detection of air movement using hair sensilla. Barth reviews the mechanics of vibrations in different types of substrates and describes vibration receptors in spiders, the most prominent and sensitive being the metatarsal lyriform organ. How spiders generate vibrations is discussed, specifically for *Cupiennius getazi*, and lycosids (wolf spiders) that combine drumming on the substrate with stridulation. This is followed by a review of vibration signals used by spiders and the kinds of sound attenuation and interference encountered in their environment.

In the final chapter, ''The Sensory Coevolution of Moths and Bats,'' Fullard discusses the classic bat–moth story. Man has been intrigued by the ability of bats to sense in the dark and by the ability of moths in flight to avoid bat predators. However, full understanding of the bat–moth interaction was achieved only in the middle of the last century, as a result of the

work of Griffin on the ultrasonic signals of bats, followed by the moth studies of Roeder. Fullard recounts the fascinating story of the evolution of the interaction and how it is continuing to evolve.

The book covers topics that are fairly well known to the average person: the sounds of crickets, the behavior of spiders in their web, and the interaction between bats and moths. Less well known, but nevertheless important topics, such as the use of hair sensilla to sense the particle velocity of sound in the new field and the sounds of aquatic insects, are not covered. Perhaps there is not enough definitive information, but these topics are a significant part of insect hearing and should have been included. The sounds of aquatic insects could be an indicator of the ecological health of fresh water systems, such as rivers, lakes, and wetlands.

I found the book informative and stimulating. Scientists involved with hearing should find the book rewarding. Hopefully it will also interest other kinds of acousticians, perhaps encouraging them to contribute to the field of animal acoustics. If we fully understood the capabilities of bats, the whole science of acoustics would be greatly advanced from where it is now.

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Speech Processing and Synthesis Toolboxes

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John Wiley & Sons, New York, 2000.
483 pp. Price: $90.95 (hardcover) ISBN: 0471349593.

The book *Speech Processing and Synthesis Toolboxes* by Donald Childers is a valuable addition to the scarce literature on speech analysis and synthesis. It provides several software toolboxes that are not available elsewhere. An extensive database of speech files also accompanies the book, and the theory behind the software is explained. It is the result of many years of experience and work in this area by the author.

This book begins with a chapter titled ''Software: Installation and Introduction,'' which contains a clear description on the differences between the two software versions provided (the runtime server version and the regular MATLAB version). I believe it was a great idea to provide the runtime server version, since many of the potential users may not have MATLAB, which is required to run the regular version. I had some difficulty installing the software, in particular, I could not find the formtk_4 files nor the Chap_10 folder.

Chapter 1 is an introduction to the book. It begins by telling the background assumed for the material covered in the text, and also presents some of the applications in speech analysis and synthesis, which I found very motivating. An introduction and explanation of some of the terminology commonly used in speech, such as fricatives, pitch, formants, etc., is given. The first software toolbox (speech_1_display) is used and demonstrated. Chapter 2 is called ''Speech Analysis Toolbox.'' It mainly shows how to use the Speech Analysis Toolbox by guiding the user through examples. It does not explain the theory behind the software since it is explained in later chapters and Appendix 6. I was very impressed by all the different types of analysis that can be done with this toolbox (time, frequency, glottal inverse filtering, pitch/jitter/formant contours, cepstral, and WRLS-VFF). This toolbox provides windows for the different types of analysis so that the user can vary the parameters at will and observe the effects on the results.

''Speech Production, Labeling and Characteristics'' is a theoretical chapter devoted to the description of general and specific aspects of speech production and its classification. Many figures and tables are provided to help understand the theory. It becomes evident in this chapter why the author stated in Sec. 1.3 that the text assumes that the speech production and characterization is for American English, which is important for potential foreign buyers. The ''Data and Measurements'' chapter describes a series of methods used in speech to obtain information about the laryngeal function. It is obvious from this chapter that there is a wide range of measurement procedures. The difficulty in directly measuring the voice source can also be seen. A toolbox is used to display and analyze speech and EGG (electroglottographic) signals.

Chapter 5 is called ''Linear Prediction.'' In this chapter the author presents the theory about the most commonly used spectral estimators, which are classified as classical and parametric estimators. This is not an easy subject, since the theory on parametric estimators is complex, and there is disagreement among authors about some concepts like zero padding and windowing; however, the author presents the concepts in a clear and precise way. ''Speech Synthesis and a Formant Speech Synthesis Toolbox'' describes the most commonly used methods for speech synthesis (Articulatory Synthesis, Formant Synthesis, and LP Synthesis), and a toolbox for speech synthesis. The use of the toolbox helps the user understand the effect of the different parameters involved in creating synthesized speech, and the steps needed to generate it.

The ''VOCOS-A Voice Conversion Toolbox'' chapter mainly describes how to use this toolbox, which provides a relatively large amount of options that can be summarized in three groups: analysis of a speech file, modification of the file parameters, and speech synthesis. The reader may not be familiar with some of the terminology used in this chapter and may need to read Appendices 6, 7, and 8 to obtain additional information. Also, the user will realize the large amount of parameters associated with a speech file while using VOCOS. Chapter 8 is called ''Time Modification of Speech Toolbox.'' This chapter shows the options of this toolbox, which consists of three main functions: (1) The analysis option, which segments the speech file into phonemes and labels them; (2) the modify option, which allows the user to change the segment boundaries and their labels; (3) the user can specify the time modification parameters for each phoneme and create the synthesized data using the time modification and synthesis option. The quality of the synthesized sample I created with this toolbox was very good.

Chapter 9 describes the ''Animated Vocal Fold Model Toolbox.'' This toolbox contains two vocal models: the Two Mass Model, and the Ribbon Model. Both of them simulate the vocal fold motion. The toolbox is very simple to use and the animated model is created in three steps: generation of the glottal area waveform, drawing of the prephonatory shape, and creation of the vocal folds animation. The main functions of the ''Articulatory Speech Synthesis Toolbox'' are described in Chap. 10, which can be summarized as follows: (1) The first four formant tracks are extracted from a target speech file; (2) the initial shape of the vocal tract is specified through a set of parameters; (3) an articulatory parameter vector is determined by applying inverse filtering; (4) an excitation waveform is designed; (5) the synthesized speech is created. The five steps previously described require that the user set a relatively high number of parameters, and the synthesis process is computationally intense (it takes 1.5 h approximately to synthesize the word ''be'' using 13 frames), which shows the user the difficulty in modeling the vocal tract. At the end of the chapter there is a list of synthesized files provided with the software. The book has 13 Appendices, which contain a glossary of terms, references, standards, the theory behind some of the toolboxes, and a list of the toolboxes.

During the entire software testing phase I was using MATLAB version 5.3. Although the software was tested by the author with version 5.2, I only had minor problems using version 5.3. Whenever I encountered problems, I used the runtime server version, which ran properly at all times. I believe the author's claim ''to strike a balance between theory and practice'' was fulfilled. The software provided contains many functions that would be too long for the reader to develop, but are important for the understanding of the theory on speech analysis and synthesis. In summary, this is a great book that will be an invaluable tool for anyone working in the speech analysis and synthesis field. The author has made an enormous effort in gathering a big amount of information in a single book. Foreign buyers must be aware that the speech production and characterization is for American English.

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