

The University of Derby
Faculty of Arts, Design and Technology

Efficient Acoustic Modelling of Large Spaces using Time Domain Methods

Analysis of Time Domain Numerical Methods
for Acoustic Modelling of Large Spaces

Simon Durbridge

April 9, 2017

Submitted for in part-fulfilment of the requirements for the
MSc in Audio Engineering.

for Bethany

Acknowledgements

I would like to dedicate this work to anyone of remote importance.

Contents

1	Introduction	1
1.1	Context	1
1.2	Problem Definition	1
2	Large Room Acoustics	3
2.1	Section Heading	3
2.2	Section Heading	3
2.2.1	Subsection Heading	4
2.3	Section Heading	5
2.3.1	Subsection Heading	6
	Appendix	7
	Problems	7

Acronyms

Use the template *acronym.tex* together with the Springer document class `SVMono` (monograph-type books) or `SVMult` (edited books) to style your list(s) of abbreviations or symbols in the Springer layout.

Lists of abbreviations, symbols and the like are easily formatted with the help of the Springer-enhanced `description` environment.

ABC	Spelled-out abbreviation and definition
BABI	Spelled-out abbreviation and definition
CABR	Spelled-out abbreviation and definition

Chapter 1

Introduction

The intro Text

1.1 Context

1.2 Problem Definition

Real time acoustic modelling could be of significant benefit to many applications; Engineers could make design changes and see results 'on the fly', and entertainment users could have more realistic experiences. These benefits should be possible for an arbitrary number of sources and receivers, in proportionally large environments with high quality results. Is it possible to further reduce computation time for simulations of large acoustic problems, to provide results in real time for the full human audio frequency range? There are two 'branches' of computation solution that should be considered: the direct solution i.e. direct outputs or audio samples from the simulation, and indirect solutions i.e. a system impulse response that may be convolved with mixed source signals in order to create an auralization of the system.//

Fig. 1.1 A visualisation of a 2D explicit FDTD simulation [?]

Chapter 2

Loudspeaker Systems & Large Room Acoustics

Abstract Acoustics is a branch of physics that aims to characterise Newton's law of motion applied to physical wave behaviour, while obeying the physical conservation law. This characterisation of sound propagation is intrinsically linked to many other branches of physics, as well as psychoacoustics and perception. In this chapter we will evaluate the acoustic wave equation for lossless gasses, and consider the application of the wave equation in bounded space.

2.1 Section Heading

Use the template *chapter.tex* together with the Springer document class SVMono (monograph-type books) or SVMult (edited books) to style the various elements of your chapter content in the Springer layout.

2.2 Section Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the L^AT_EX automatism for all your cross-references and citations.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

Use the standard `equation` environment to typeset your equations, e.g.

$$a \times b = c , \tag{2.1}$$

however, for multiline equations we recommend to use the `eqnarray` environment¹.

$$a \times b = c$$

¹ In physics texts please activate the class option `vecphys` to depict your vectors in *boldface-italic* type - as is customary for a wide range of physical subjects.

$$\mathbf{a} \cdot \mathbf{b} = \mathbf{c} \quad (2.2)$$

2.2.1 Subsection Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the \LaTeX automatism for all your cross-references and citations as has already been described in Sect. 2.2.

Please do not use quotation marks when quoting texts! Simply use the `quotation` environment – it will automatically render Springer’s preferred layout.

2.2.1.1 Subsubsection Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the \LaTeX automatism for all your cross-references and citations as has already been described in Sect. 2.2.1, see also Fig. ??²

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

Paragraph Heading Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the \LaTeX automatism for all your cross-references and citations as has already been described in Sect. 2.2.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

For typesetting numbered lists we recommend to use the `enumerate` environment – it will automatically render Springer’s preferred layout.

1. Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.
 - a. Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.
 - b. Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.
2. Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.

² If you copy text passages, figures, or tables from other works, you must obtain *permission* from the copyright holder (usually the original publisher). Please enclose the signed permission with the manuscript. The sources must be acknowledged either in the captions, as footnotes or in a separate section of the book.

Subparagraph Heading In order to avoid simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Use the \LaTeX automatism for all your cross-references and citations as has already been described in Sect. 2.2, see also Fig. ??.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

For unnumbered list we recommend to use the `itemize` environment – it will automatically render Springer’s preferred layout.

- Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development, cf. Table 2.1.
 - Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.
 - Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.
- Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.

Run-in Heading Boldface Version Use the \LaTeX automatism for all your cross-references and citations as has already been described in Sect. 2.2.

Run-in Heading Italic Version Use the \LaTeX automatism for all your cross-references and citations as has already been described in Sect. 2.2.

Table 2.1 Please write your table caption here

Classes	Subclass	Length	Action Mechanism
Translation	mRNA ^a	22 (19–25)	Translation repression, mRNA cleavage
Translation	mRNA cleavage	21	mRNA cleavage
Translation	mRNA	21–22	mRNA cleavage
Translation	mRNA	24–26	Histone and DNA Modification

^a Table foot note (with superscript)

2.3 Section Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the \LaTeX automatism for all your cross-references and citations as has already been described in Sect. 2.2.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

If you want to list definitions or the like we recommend to use the Springer-enhanced `description` environment – it will automatically render Springer’s preferred layout.

- Type 1 That addresses central themes pertaining to migration, health, and disease. In Sect. 2.1, Wilson discusses the role of human migration in infectious disease distributions and patterns.
- Type 2 That addresses central themes pertaining to migration, health, and disease. In Sect. 2.2.1, Wilson discusses the role of human migration in infectious disease distributions and patterns.

2.3.1 Subsection Heading

In order to avoid simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Use the \LaTeX automatism for all your cross-references and citations as has already been described in Sect. 2.2.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

If you want to emphasize complete paragraphs of texts we recommend to use the newly defined Springer class option `graybox` and the newly defined environment `svgraybox`. This will produce a 15 percent screened box 'behind' your text.

If you want to emphasize complete paragraphs of texts we recommend to use the newly defined Springer class option and environment `svgraybox`. This will produce a 15 percent screened box 'behind' your text.

2.3.1.1 Subsubsection Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the \LaTeX automatism for all your cross-references and citations as has already been described in Sect. 2.2.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

Theorem 2.1. *Theorem text goes here.*

Definition 2.1. Definition text goes here.

Proof. Proof text goes here. \square

Paragraph Heading Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the \LaTeX automatism for all your cross-references and citations as has already been described in Sect. 2.2.

Note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

Theorem 2.2. *Theorem text goes here.*

Definition 2.2. Definition text goes here.

Proof. Proof text goes here. □

Acknowledgements If you want to include acknowledgments of assistance and the like at the end of an individual chapter please use the `acknowledgement` environment – it will automatically render Springer’s preferred layout.

Appendix

When placed at the end of a chapter or contribution (as opposed to at the end of the book), the numbering of tables, figures, and equations in the appendix section continues on from that in the main text. Hence please *do not* use the `appendix` command when writing an appendix at the end of your chapter or contribution. If there is only one the appendix is designated “Appendix”, or “Appendix 1”, or “Appendix 2”, etc. if there is more than one.

$$a \times b = c \tag{2.3}$$

Problems

2.1. A given problem or Exercise is described here. The problem is described here. The problem is described here.

2.2. Problem Heading

- (a) The first part of the problem is described here.
- (b) The second part of the problem is described here.

Methods

Difference Time Domain Method

Finite Difference Time Domain Method

Time Domain Method

Modelling Strategies

Work

