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Timothy G. Feeman

# The Mathematics of Medical Imaging

A Beginner's Guide

Second Edition

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# **Mathematics Of Medical Imaging**

**Timothy G. Feeman** 

#### **Mathematics Of Medical Imaging:**

Introduction to the Mathematics of Medical Imaging Charles L. Epstein, 2008-01-01 At the heart of every medical imaging technology is a sophisticated mathematical model of the measurement process and an algorithm to reconstruct an image from the measured data This book provides a firm foundation in the mathematical tools used to model the measurements and derive the reconstruction algorithms used in most imaging modalities in current use In the process it also covers many important analytic concepts and techniques used in Fourier analysis integral equations sampling theory and noise analysis This text uses X ray computed tomography as a pedagogical machine to illustrate important ideas and incorporates extensive discussions of background material making the more advanced mathematical topics accessible to readers with a less formal mathematical education The mathematical concepts are illuminated with over 200 illustrations and numerous exercises New to the second edition are a chapter on magnetic resonance imaging MRI a revised section on the relationship between the continuum and discrete Fourier transforms a new section on Grangreat's formula an improved description of the gridding method and a new section on noise analysis in MRI Audience The book is appropriate for one or two semester courses at the advanced undergraduate or beginning graduate level on the mathematical foundations of modern medical imaging technologies The text assumes an understanding of calculus linear algebra and basic mathematical analysis Contents Preface to the Second Edition Preface How to Use This Book Notational Conventions Chapter 1 Measurements and Modeling Chapter 2 Linear Models and Linear Equations Chapter 3 A Basic Model for Tomography Chapter 4 Introduction to the Fourier Transform Chapter 5 Convolution Chapter 6 The Radon Transform Chapter 7 Introduction to Fourier Series Chapter 8 Sampling Chapter 9 Filters Chapter 10 Implementing Shift Invariant Filters Chapter 11 Reconstruction in X Ray Tomography Chapter 12 Imaging Artifacts in X Ray Tomography Chapter 13 Algebraic Reconstruction Techniques Chapter 14 Magnetic Resonance Imaging Chapter 15 Probability and Random Variables Chapter 16 Applications of Probability Chapter 17 Random Processes Appendix A Background Material Appendix B Basic Analysis Index The Mathematics of Medical Imaging Timothy G. Feeman, 2015 The basic mathematics of computerized tomography the CT scan are aptly presented for an audience of undergraduates in mathematics and engineering Assuming no prior background in advanced mathematical analysis topics such as the Fourier transform sampling and discrete approximation algorithms are introduced from scratch and are developed within the context of medical imaging A chapter on magnetic resonance imaging focuses on manipulation of the Bloch equation the system of differential equations that is the foundation of this important technology Extending the ideas of the acclaimed first edition new material has been added to render an even more accessible textbook for course usage This edition includes new discussions of the Radon transform the Dirac delta function and its role in X ray imaging Kacmarz's method and least squares approximation spectral filtering and more Copious examples and exercises several new computer based exercises and additional graphics have been added to

further delineate concepts The use of technology has been revamped throughout with the incorporation of the open source programming environment R to illustrate examples and composition of graphics All R code is available as extra source material on SpringerLink From the reviews of the first edition This book is valuable for it addresses with care and rigor the relevance of a variety of mathematical topics to a real world problem This book is well written It serves its purpose of focusing a variety of mathematical topics onto a real world application that is in its essence mathematics The Journal of Nuclear Medicine Vol 51 12 December 2010 This new book by Timothy Feeman truly intended to be a beginner s guide makes the subject accessible to undergraduates with a working knowledge of multivariable calculus and some experience with vectors and matrix methods author handles the material with clarity and grace The Mathematical Association of America February 2010 All theoretical material is illustrated with carefully selected examples which are easy to follow I highly recommend this interesting accessible to wide audience and well written book dealing with mathematical techniques that support recent ground breaking discoveries in biomedical technology both to students and to specialists Zentralblatt MATH Vol 1191 2010 The Mathematics of Medical Imaging Timothy G. Feeman, 2010-03-10 In 1979 the Nobel Prize for Medicine and Physiology was awarded jointly to Allan McLeod Cormack and Godfrey Newbold Houns eld the two pioneering scienti engineers primarily responsible for the development in the 1960s and early 1970s of computerized axial tomography popularly known as the CAT or CT scan In his papers 13 Cormack then a Professor at Tufts University in Massachusetts dev oped certain mathematical algorithms that he envisioned could be used to create an image from X ray data Working completely independently of Cormack and at about the same time Houns eld a research scientist at EMI Central Research Laboratories in the United Kingdom designed the rst operational CT scanner as well as the rst commercially available model See 22 and 23 Since 1980 the number of CT scans performed each year in the United States has risen from about 3 million to over 67 million What few people who have had CT scans probably realize is that the fundamental problem behind this procedure is essentially mathematical If we know the values of the integral of a two or three dimensional fu tion along all possible cross sections then how can we reconstruct the function itself This particular example of what is known as an inverse problem was studied by Johann Radon an Austrian mathematician in the early part of the twentieth century

Medical Image Processing James A. Green,1994 The Mathematics of Medical Imaging Timothy G. Feeman,2010 Medical imaging is a major part of twenty first century health care This introduction explores the mathematical aspects of imaging in medicine to explain approximation methods in addition to computer implementation of inversion algorithms

The Radon Transform and Medical Imaging Peter Kuchment,2014-03-20 This book surveys the main mathematical ideas and techniques behind some well established imaging modalities such as X ray CT and emission tomography as well as a variety of newly developing coupled physics or hybrid techniques including thermoacoustic tomography The Radon Transform and Medical Imaging emphasizes mathematical techniques and ideas arising across the spectrum of medical

imaging modalities and explains important concepts concerning inversion stability incomplete data effects the role of interior information and other issues critical to all medical imaging methods For nonexperts the author provides appendices that cover background information on notation Fourier analysis geometric rays and linear operators The vast bibliography with over 825 entries directs readers to a wide array of additional information sources on medical imaging for further study

Mathematical Models for Registration and Applications to Medical Imaging Otmar Scherzer,2006-10-03 Image registration is an emerging topic in image processing with many applications in medical imaging picture and movie processing The classical problem of image registration is concerned with nding an appropriate transformation between two data sets This fuzzy de nition of registration requires a mathematical modeling and in particular a mathematical speci cation of the terms appropriate transformations and correlation between data sets Depending on the type of application typically Euler rigid plastic elastic deformations are considered The variety of similarity p measures ranges from a simpleL distance between the pixel values of the data to mutual information or entropy distances This goal of this book is to highlight by some experts in industry and medicine relevant and emerging image registration applications and to show new emerging mathematical technologies in these areas Currently many registration application are solved based on variational prin ple requiring sophisticated analysis such as calculus of variations and the theory of partial differential equations to name but a few Due to the numerical compl ity of registration problems ef cient numerical realization are required Concepts like multi level solver for partial differential equations non convex optimization and so on play an important role Mathematical and numerical issues in the area of registration are discussed by some of the experts in this volume Moreover the importance of registration for industry and medical imaging is discussed from a medical doctor and from a manufacturer point of view

Mathematics and Computer Science in Medical Imaging Max A. Viergever, Andrew Todd-Pokropek, 2012-12-06 Medical imaging is an important and rapidly expanding area in medical science Many of the methods employed are essentially digital for example computerized tomography and the subject has become increasingly influenced by develop ments in both mathematics and computer science The mathematical problems have been the concern of a relatively small group of scientists consisting mainly of applied mathematicians and theoretical physicists Their efforts have led to workable algorithms for most imaging modalities However neither the fundamentals nor the limitations and disadvantages of these algorithms are known to a sufficient degree to the physicists engineers and physicians trying to implement these methods It seems both timely and important to try to bridge this gap This book summarizes the proceedings of a NATO Advanced Study Institute on these topics that was held in the mountains of Tuscany for two weeks in the late summer of 1986 At another quite different earlier meeting on medical imaging the authors noted that each of the speakers had given there a long introduction in their general area stated that they did not have time to discuss the details of the new work but proceeded to show lots of clinical results while excluding any mathematics associated with the area.

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Imaging Kajji Santospirito,2008 Mathematics and Physics of Emerging Biomedical Imaging National Research Council, Division on Engineering and Physical Sciences, Commission on Physical Sciences, Mathematics, and Applications, Committee on the Mathematics and Physics of Emerging Dynamic Biomedical Imaging, 1996-02-28 This cross disciplinary book documents the key research challenges in the mathematical sciences and physics that could enable the economical development of novel biomedical imaging devices It is hoped that the infusion of new insights from mathematical scientists and physicists will accelerate progress in imaging Incorporating input from dozens of biomedical researchers who described what they perceived as key open problems of imaging that are amenable to attack by mathematical scientists and physicists this book introduces the frontiers of biomedical imaging especially the imaging of dynamic physiological functions to the educated nonspecialist Ten imaging modalities are covered from the well established e.g. CAT scanning MRI to the more speculative e.g. electrical and magnetic source imaging For each modality mathematics and physics research challenges are identified and a short list of suggested reading offered Two additional chapters offer visions of the next generation of surgical and interventional techniques and of image processing A final chapter provides an overview of mathematical issues that cut across the various modalities

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