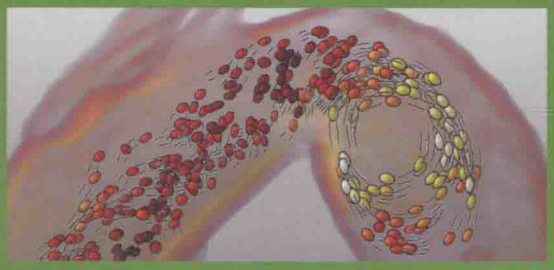
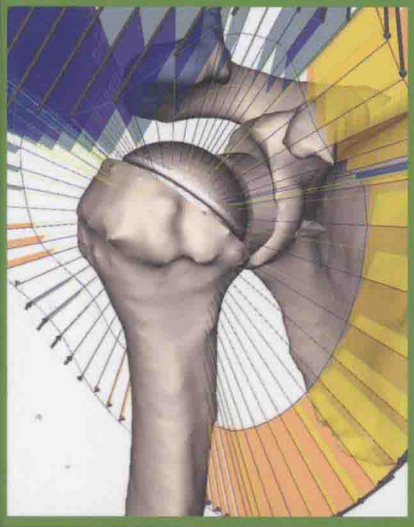
Edition 2

Visual Computing for Medicine

Theory, Algorithms, and Applications





Bernhard Preim
Charl Botha

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VISUAL COMPUTING FOR MEDICINE

THEORY, ALGORITHMS, AND APPLICATIONS

SECOND EDITION

BERNHARD PREIM
CHARL BOTHA

ELSEVIER

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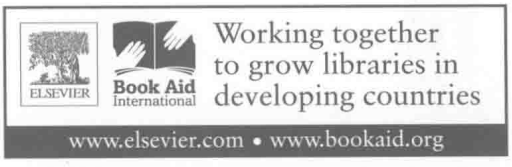

VISUAL COMPUTING FOR MEDICINE

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Foreword to the Second Edition

Visual Computing for Medicine is an excellent textbook for students, researchers, and practitioners in the field of medical visualization. It is an authoritative resource for medical experts and technical personnel as well.

The book is the sequel to the highly successful first edition which immediately established itself as the reference work in this rather new and vibrant research topic in medical informatics. Dirk Bartz as one of the co-authors of the first edition unfortunately and untimely passed away in 2010. This left a sorely felt void in our community and prevented him from collaborating on the second edition.

This second edition provides a substantially updated, restructured, and extended view on the current state of the field. In a recent talk Donald Knuth, the preeminent computer scientist, was asked about relevant open research directions in computer science. After some reflections, he said that medical visualization was one of the important topics in this respect. This was good to hear, though he quickly (and regrettably) added that according to his opinion not many problems have been solved yet. I take the liberty to slightly disagree and put this textbook forward as compelling and written evidence to the contrary. And what an evidence it is! On over one-thousand pages the authors survey the intensive and rapid developments in our area. The relatively short period between first and second edition and the considerable amount of added material in extent and volume are very clear indications of the fast-paced evolution of visualization in medicine.

The book is concerned with diagnosis, treatment, and therapy planning with a focus on the currently most prevalent 2D and 3D imaging modalities. It thoroughly discusses the elaborate pipeline from data acquisition, analysis, and interpretation to advanced volume visualization and exploration techniques. Human computer interaction in the context of medical visualization has been covered in detail and encompasses significant topics like volume interaction, labeling, and measurement. Important application areas and advanced visualization techniques for blood vessels, virtual endoscopy, ENT surgery planning, perfusion, and diffusion data are extensively dealt with.

The book is very well structured, where the 22 chapters are grouped into five focal themes. The authors primarily organize the book according to techniques as most of these are applicable to a variety of medical tasks. Some of the material has been combined into completely new chapters like the one on projection-based medical visualization techniques. Hints at further readings at the end of each chapter point the interested reader to additional useful material not discussed within the chapter. Various advanced topics, which are of interest to the software engineer but are maybe too detailed for the general audience, are included in clearly marked break-out sections. The substantial reference list is another eloquent testimony of the breadth and depth of the topic.

The authors are highly recognized experts in the field of medical visualization. They have achieved the impressive feat of comprehensively covering a dynamic and rapidly emerging subject. The book provides informative, broad, and didactically well-organized information for specialists from diverse areas of expertise. The book will be the standard guide to medical visualization for years to come.

Dr. Eduard Gröller
Vienna University of Technology

Preface to the Second Edition

This second edition of "Visualization in Medicine" reflects the dynamic development of medical imaging, algorithmic processing and applications in medical research and clinical use after 2006. After the tragic passing of Dirk Bartz in March 2010, Charl Botha stepped in to prepare this new edition. In addition to careful rewriting of all chapters, we added a number of completely new chapters and reorganized and updated others significantly. Advances in imaging technology, e.g., hybrid devices, ultra high field MRI, intraoperative imaging, and the trend towards interventional procedures, are reflected in various parts of the book.

Since more and more advanced applications, e.g., in processing the complex multi-modal data of cardiac or neuroradiological MRI, have entered the stage of routine clinical use, human-computer interaction is becoming increasingly important. A comprehensive chapter was added to introduce HCI concepts with applications in medicine, incorporating recent interaction styles and technology. Also the chapter related to clinical practice was strongly extended by discussing also nuclear medicine, radiation treatment and medical team meetings in addition to the classical diagnostic settings.

Another essential trend is the combination of biomedical simulations with advanced visual exploration. As a consequence, we prepared a chapter that introduces basic techniques, such as the generation of simulation grids from medical imaging data and flow visualization, to explore the results. We study a number of specific applications, such as the simulation of blood flow to better predict the success of treatment options.

While the first edition of this book was focused on visual exploration, we have added discussions of data analysis techniques and their integration in what is widely called "visual analytics". This relates, e.g., to cluster analysis and dimension reduction. We discuss these techniques in relation to high-dimensional data, such as perfusion data and diffusion tensor imaging data. They are, however, also relevant for volume classification, the basic process of assigning transfer functions to medical volume data.

Computer-assisted surgery (CAS), one of the most essential applications for medical visualization technology, has matured in the last decade. We use experiences gained in the design and evaluation of such systems to prepare a general introductory chapter on CAS, followed by chapters treating selected application areas, such as orthopedics. Intraoperative imaging and intraoperative guidance have grown in importance in the last years. The chapter devoted to this topic was significantly extended, e.g., with techniques developed for soft-tissue surgery. Even the chapters discussing basic medical visualization techniques, such as surface and direct volume rendering, deserved a careful revision.

Among others, GPU-based techniques play a more prominent role now. GPU-based rendering enables a huge step in improving image quality without compromising performance. We discuss how these improvements are employed, e.g., in virtual endoscopy—another chapter that could be improved by taking advantage of many new and refined techniques.

The increasing size and complexity of medical image data motivated the development of visualization techniques that radically differ from the classical surface and volume rendering techniques. To convey the complex information of medical flow data along with the relevant anatomy, for example, benefits from illustrative techniques that render the anatomy sparsely. Thus, illustrative rendering plays a more prominent role in this second edition discussing the extraction of various features from medical volume data and related meshes as a basis for rendering.

A second radically new class of visualization techniques are map-based techniques. While some isolated techniques, such as stretched curved planar reformations of vascular structures, have been introduced more than a decade ago, we can now discuss this topic in a more general fashion in a separate chapter. DTI was rather new when the first edition was prepared. It is meanwhile a mature technique that is discussed in a wider scope as one out of several techniques to understand *brain connectivity*.

Medical education in anatomy, interventional radiology and surgery remains an important use case of visual computing. One comprehensive chapter is dedicated to such applications with a focus on recent trends, such as web-based training platforms, and (automatic) skills assessment.

Companion Website

Visit this book's companion website for this work: http://medvisbook.com/

Author Biography

PROF. DR.-ING. BERNHARD PREIM was born in 1969 in Magdeburg, Germany. He received the diploma in computer science in 1994 (minor in mathematics) and a Ph.D. in 1998 from the Otto-von-Guericke University of Magdeburg (Ph.D. thesis "Interactive Illustrations and Animations for the Exploration of Spatial Relations"). In 1999 he finished work on a German textbook on Human Computer Interaction which appeared at Springer. He then moved to Bremen where he joined the staff of MeVis (Center for Medical Diagnosis and Visualization Systems, Bremen). In close collaboration with radiologists and surgeons he directed the work on "computer-aided planning in liver surgery" focusing on virtual resection, automatic resection proposals, visualization of vascular structures, and the integration of measurements in 3D visualizations. This work was largely influenced by Prof. Heinz-Otto Peitgen, the founder and director of MEVIS. In June 2002 Bernhard Preim received the post-doctoral lecture qualification for computer science from the University of Bremen. Since Mars 2003 he is full professor for "Visualization" at the computer science department at the Otto-von-Guericke-University of Magdeburg, heading a research group which is focussed on medical visualization and applications in surgical education and surgery planning. The focus of this research is illustrative medical visualization, visual exploration of blood flow, virtual endoscopy, and in particular surgery in the ear, nose, throat region. These developments are summarized in a textbook Visualization in Medicine (Co-author Dirk Bartz). His continuous interest in HCI lead to another textbook "Interaktive Systeme" (Co-author: R. Dachselt) (Springer, 2010). His regular teaching activities include "Medical Visualization", "Computer-Assisted Diagnosis and Treatment" as well as the introductory courses on "Visualization" and "Interactive Systems".

Bernhard Preim founded the working group Medical Visualization in the German Society for Computer Science in 2003 and acted as speaker until 2012. He is also a long-term member of CURAC, the German society for computer-assisted surgery, where he became board member in 2007, and vicepresident in 2009. He was Co-Chair and Co-Organizer of the first and second Eurographics Workshop on Visual Computing in Biology and Medicine (VCBM, together with Charl Botha) and is now member of the steering committee of that workshop. He is the chair of the scientific advisory board of ICCAS (International Competence Center on Computer-Assisted Surgery, since 2010), member of the advisory boards of Fraunhofer Heinrich-Hertz-Institute, Berlin and the Institute for Innovative Surgical Training Technologies (ISTT), Leipzig. He is also regularly a Visiting Professor at the University of Bremen where he closely collaborates with Fraunhofer MEVIS. At the University of Magdeburg, Bernhard Preim is member of the Board (since 2008). Bernhard Preim is married with the radiologist Uta Preim (Medical Doctor), born Hahn and has two children.

DR. CHARL P. BOTHA graduated from the University of Stellenbosch, South Africa, in 1997 with a degree in electronics engineering, followed by an M.Sc. in digital signal processing, in 1999, and finally a Ph.D. in medical visualization from the Delft University of Technology (TU Delft) in the Netherlands, under the supervision of Frits Post, one of the pioneers of scientific visualization in Europe.

After completing his Ph.D., he was appointed (2006) and soon after tenured (2007) as an assistant professor of Visualization at the TU Delft, where he started and headed the medical visualization lab. He also had an appointment at LKEB, the medical image processing section of the Department of Radiology at the Leiden University Medical Center (LUMC), in order to cultivate and expand the fruitful research collaboration between the technical university and the academic hospital.

His research focused on surgical planning and guidance, and visual analysis for medical research. He has published on, among other topics, anatomical modeling, virtual colonoscopy, shoulder replacement, and diffusion tensor imaging. Together with Bernhard Preim he initiated the Eurographics Workshop series on Visual Computing for Biology and Medicine, acted as co-chair in 2008 and 2010, and served as editor together with Prof. Preim of the Computers and Graphics special issue on VCBM.

Prior to his Ph.D. he worked in industry designing embedded image processing systems and algorithms for two different companies. Shortly after the Ph.D., he co-founded Treparel Information Solutions, a company specializing in data mining, and he acts as science advisor to Clinical Graphics, a spin-off company founded by an ex-Ph.D. student to commercialize surgical planning research results. He recently also decided to make the move back into industry full-time, where he has started a company that focuses on bringing computer science, imaging, and visualization research into real-world practice. He remains actively involved with the medical visualization community through the MedVis.org website and its related resources. Charl is married to Stella Botha-Scheepers, MD, Ph.D., a rheumatologist and internist, with whom he has two children.

Contents

ACKNOWLEDGMENTS xvii

FOREWORD TO THE SECOND EDITION xix

PREFACE TO THE SECOND EDITION xxi

AUTHOR BIOGRAPHY xxiii

01 INTRODUCTION 1
1.1 Visualization in Medicine as a Specialty of Scientific Visualization 1
1.2 Computerized Medical Imaging 3
1.3 2D and 3D Visualizations 7
1.4 Further Information 8
1.5 Organization 9

PART I ACQUISITION, ANALYSIS, AND INTERPRETATION OF MEDICAL VOLUME DATA

02 ACQUISITION OF MEDICAL IMAGE DATA 15
2.1 Introduction 15
2.2 Medical Image Data 16
2.3 Data Artifacts and Signal Processing 19
2.3.1 Sampling Theorem 19
2.3.2 Undersampling and Aliasing 21
2.3.3 Interpolation Artifacts 22
2.4 X-Ray Imaging 24
2.4.1 Angiography 26
2.4.2 Rotational X-Ray 26
2.4.3 Discussion 28
2.4.4 Current and Future Developments of X-Ray Imaging 28
2.5 Computed Tomography 29
2.5.1 Computed Tomography Compared to X-Ray Imaging 30
2.5.2 Principle of CT Data Generation 30

2.5.3 Standardization with Hounsfield Units 31
2.5.4 Parameters of CT Scanning 32
2.5.5 Artifacts in CT Image Acquisition 35
2.5.6 Current and Future Developments of CT Scanners 37
2.5.7 Discussion 40
2.6 Magnetic Resonance Imaging 40
2.6.1 Principles of MRI 41
2.6.2 Parameters of MR Scanning 44
2.6.3 Artifacts in MRI Data 47
2.6.4 Functional MRI 48
2.6.5 Ultra-High-Field MRI 50
2.6.6 Diffusion Tensor Imaging 51
2.6.7 Discussion 52
2.7 Ultrasound 52
2.8 Imaging in Nuclear Medicine 55
2.8.1 Positron Emission Tomography—PET 56
2.8.2 Hybrid PET/CT and PET/MRI Scanners 57
2.8.3 Single Photon Emission Computed Tomography—SPECT 60
2.9 Intraoperative Imaging 61
2.9.1 CT- and MR-Guided Interventions 62
2.9.2 Fluoroscopy 63
2.9.3 Intraoperative Ultrasound 63
2.9.4 Intraoperative MRI 64
2.10 Summary 65

03 AN INTRODUCTION TO MEDICAL VISUALIZATION IN CLINICAL PRACTICE 69
3.1 Introduction 69
3.2 Diagnostic Accuracy 70
3.3 Visual Perception 73
3.3.1 Gray Value Perception 73
3.3.2 Color Spaces, Color Scales, and Color Perception 77
3.3.3 Visual Perception and Attention in the Diagnosis Of Medical Volume Data 81
3.4 Storage of Medical Image Data 81
3.4.1 Scope of Dicom 82
3.4.2 Structure of Dicom Data 82
3.5 Conventional Film-Based Diagnosis 83
3.5.1 Cooperation of Radiologists and Radiology Technicians 85
3.5.2 Tasks in Conventional Film-Based Diagnosis 85
3.6 Soft-Copy Reading 86
3.6.1 Digital Radiology Departments 86
3.6.2 Tasks in Soft-Copy Reading 88

3.6.3 Digital Hanging Protocol 92
3.6.4 Computer-Aided Detection 93
3.6.5 Diagnosis with 3D Visualizations 97
3.6.6 Guidelines for Soft-Copy Reading 100
3.7 Medical Visualization in Nuclear Medicine 101
3.8 Medical Image Data in Radiation Treatment Planning 102
3.8.1 Conformant and Intensity-Modulated Radiation Treatment 105
3.8.2 Brachytherapy 107
3.9 Medical Team Meetings 107
3.10 Concluding Remarks 109

04 IMAGE ANALYSIS FOR MEDICAL VISUALIZATION 111
4.1 Introduction 111
4.2 Preprocessing and Filtering 112
4.2.1 ROI Selection 113
4.2.2 Resampling 113
4.2.3 Histogram and Histogram Transformation 114
4.2.4 General Noise Reduction Techniques 116
4.2.5 Inhomogeneity Correction 122
4.2.6 Gradient Filtering 123
4.3 An Introduction to Image Segmentation 124
4.3.1 Requirements 125
4.3.2 Manual Segmentation 125
4.3.3 Threshold-Based Segmentation 126
4.3.4 Region Growing 128
4.3.5 Watershed Segmentation 129
4.4 Graph-Based Segmentation Techniques 132
4.4.1 Livewire Segmentation 132
4.4.2 Contour-Based Segmentation with Variational Interpolation 136
4.4.3 Graph Cuts 137
4.4.4 Random Walker Segmentation 138
4.5 Advanced and Model-Based Segmentation Methods 139
4.5.1 Active Contour Models 140
4.5.2 Level Sets and Fast Marching Methods 141
4.5.3 Statistical Shape Models 143
4.5.4 Active Appearance Models 146
4.5.5 Incorporating Model Assumptions in Region Growing Segmentation 148
4.5.6 Application: Tumor Segmentation 148
4.5.7 Verification and Representation of Segmentation Results 152
4.6 Interaction for Segmentation 153
4.6.1 General Techniques for Correcting Pre-Segmentations 155
4.6.2 Mesh-Based Correction of Segmentation Results 155
4.6.3 Interactive Morphological Image Processing 159

4.6.4 Interaction Techniques for Semi-Automatic Segmentation 160
4.7 Validation of Segmentation Methods 162
4.7.1 Phantom Studies Versus Clinical Data 162
4.7.2 Validation Metrics 163
4.7.3 Validation with Public Databases 164
4.8 Registration and Fusion of Medical Image Data 165
4.8.1 Transformation 166
4.8.2 Fitting 167
4.8.3 Model-Based Registration 169
4.8.4 Efficient Registration 170
4.8.5 Visualization 170
4.9 Summary 172

05 HUMAN-COMPUTER INTERACTION FOR MEDICAL VISUALIZATION 177
5.1 Introduction 177
5.2 User and Task Analysis 179
5.2.1 Task Analysis Methods 179
5.2.2 What has to be Analyzed? 181
5.2.3 Representations of Task Analysis 181
5.2.4 Understanding the User 189
5.2.5 Case Study: Task Analysis for Medical Team Meetings 190
5.3 Metaphors 191
5.4 Prototyping 193
5.5 User Interface Principles and User Experience 194
5.5.1 General User Interface Principles 195
5.5.2 User Interface Principles for Medical Applications 197
5.5.3 User Experience 198
5.6 3D Interaction Techniques 199
5.6.1 Selection Tasks 199
5.6.2 3D Rotation 200
5.6.3 Object Placement 202
5.6.4 Navigation 203
5.7 Input Devices 205
5.7.1 6 Dof Input Devices 207
5.7.2 Tactile Input Devices 210
5.8 HCI in the Operating Room 212
5.9 Mobile Computing 216
5.10 Evaluation 220
5.10.1 Formative and Summative Evaluations 221
5.10.2 Inspection-Based and Empirical Evaluations 222
5.10.3 Evaluation of Interactive Segmentation Techniques 222
5.10.4 Post Market Clinical Follow Up 223
5.11 Conclusion 223