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Editor

Biomedical Image Processing

With 254 Figures
To Verena – the beauty and the beauty of images
YATBIP: Yet another textbook on biomedical image processing? – Hopefully not...

Based on the tutorial SC086 – *Fundamentals of Medical Image Processing* regularly offered at the International SPIE Symposium on Medical Imaging, the Springer-Verlag Series Editor of *Biological and Medical Physics, Medical Engineering* invited me in January 2009 to compile this book. Actually, the idea of providing a “suitable” textbook – comprehensive but short, up-to-date but essential, and detailed but illustrative – for novices like experts, and at reasonable costs, is not new. For years, the lack of any such textbook in image processing covering all of the special needs in biology and medicine is evident. In any teaching lecture, tutorial as well as graduate class. I’m always asked by the students to suggest literature but cannot answer satisfyingly, simply because there isn’t a “suitable” textbook yet.

So we aimed at compiling a high-quality collection of chapters, written for scientists, researchers, lectures and graduate students as well, covering the recent advantages in the broad field of biomedical imaging and image processing in an exemplary way. In February 2009, several fruitful discussions with colleagues at SPIE Medical Imaging convinced me to face the challenge, and I started recruiting author teams for contributions. Finally, 47 authors from 11 nations all over the world collaborated – all of them leading experts in their field. Intensive efforts were made to direct all authors towards a similar style of presentation and equal degree of technical details. Beside some written guidelines, the overview chapter was provided to the authors as an example before they started writing. All authors first provided a short outline and a detailed table of content, which were distributed between all contributors together with a strictly enforced time line. In October 2009, submission of chapters started, and each manuscript was edited carefully. Editor requests have been processed by the authors improving completeness and clarity of presentation, and finally in June 2010, the manuscript was submitted to the publisher.
Fig. 1. *Eierlegende Wollmilchsau*. Every morning, this special animal provides a cooked egg with chilled fresh milk. Its wool is used for high-quality clothes and the meat for excellent dining. It is the first *all-in-one* approach documented in history
(Courtesy of: http://neulehrer.wordpress.com/)

As a result, this book has appeared as uniform monograph with an overview chapter contributed by the editor, followed by some twenty chapters focusing on particular parts selected from biomedical imaging and image processing. Each chapter gives an introduction and overview of recent trends in its field and provides particular case examples, usually taken from the author’s own research.

Primarily addressing engineers and system developers in computer sciences, the book covers the entire processing pipeline of biomedical imaging. In particular, the following parts are included, with about three chapters in each of it:

1. Image formation
2. Image enhancement
3. Feature extraction and selection
4. Segmentation
5. Classification and measurements
6. Image data visualization
7. Image management and integration
8. Evaluation and customizing

Many people might object me at this point, because we clearly aimed at reaching the unreachable. In Germany, we have the common phrase “eierlegende Wollmilchsau”, a metaphor that directly translates to “egg-providing wool-milk-pig” describing the union of all benefits (Fig. 1).

You as the reader shall judge our success realizing this all-in-one approach: YATBIP or eierlegende Wollmilchsau? Any feedback is deeply welcome and should be directed personally to me as the editor.

Facing now the final manuscript, I want to thank Claus Ascheron for encouraging me to initiate this project, and all contributors for timely delivering their high-quality material and appropriately responding to the editorial remarks and suggestions. Jens Hoffmann was assisting me in \LaTeX{} programming and Max Jung helped in text and image conversion and optimization.

Also, I want to mention Peter Jentsch and Dirk Bartz, who have passed away during the very last iterations of the manuscript, which leaves me behind speechless. We have included the obituaries in the next pages.

Aachen, December 2010

*Thomas M. Deserno, né Lehmann*
Obituaries

**Prof. Dr. Peter Jensch** died unexpectedly during the period of the proof-reading of this book chapter on April 15, 2010 after a fulfilling life. Peter Jensch was the initiator of the DICOM research activities at the OFFIS - Institute for Information Technology, Oldenburg, Germany, in the early 1990s and was pushing this topic forward for the rest of his life. The most popular result of this engagement is the well-known Open Source DICOM toolkit DCMTK that is hosted and maintained by OFFIS since 1993. Against this background, all members of the DICOM team at OFFIS would like to thank Peter Jensch for establishing this extraordinary project and for being such a likeable, energetic boss, mentor, and colleague to us. Without him, OFFIS would not be the popular name in the world of DICOM it is today and we all would not have such encouraging opportunities and research projects we still enjoy. As Chap. 17 of this book is the last publication Peter Jensch participated in and since the content of this chapter is the very topic that strongly influenced his work, we like to use this opportunity to express our sincere gratitude to Peter Jensch.

Oldenburg, June 2010

Michael Onken
Marco Eichelberg
Jörg Riesmeier
Prof. Dr. Dirk Bartz died unexpectedly on March 28, 2010 while attending the thirtieth Vattenfall Berlin Half Marathon. Running half-marathon in Berlin was one of his favorite activities.

During his academic career, Dirk strongly supported the idea of building a German Interest Group on Medical Visualization and actively took part the whole time giving advice to many students; particularly supporting female researchers was an important issue. Furthermore, Dirk organized many tutorials at Visualization, Eurographics, and Computer-Assisted Radiology and Surgery (CARS).

In 2005, I was very glad that Dirk joined the effort of writing a textbook on “Visualization in Medicine”. For an 18 month period, we communicated daily on the various aspects of the book. It was enlightening and a pleasure to discuss with Dirk all the time. He was always perfectly reliable and good-humored even in situations where he had a very high workload.

In the end of 2006, Dirk became appointed as Full Professor for Computer-Assisted Surgery at the International Center for Computer-Assisted Surgery (ICCAS), Leipzig, Germany, and started to build a new research group. He focused on visualization techniques, such as illustrative rendering, perceptual studies (from Dirk I learned the term “psychophysical studies”), and applications in neurosurgery and Ear, Nose and Throat (ENT) surgery.

Dirk belonged to the core team which tried to establish a new workshop series “Visual Computing in Biology and Medicine”. It was quite natural that Dirk would host the second event, scheduled to take place in July in Leipzig. Until the very last days of his life, he discussed strategies for this workshop.

Dirk was only 42 years old, leaving behind Heidi, his wife, and his two little sons.

Magedeburg, June 2010

Berhard Preim
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<tbody>
<tr>
<td>1D</td>
<td>One-Dimensional</td>
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<tr>
<td>2D</td>
<td>Two-Dimensional</td>
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<td>Three-Dimensional</td>
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<td>4D</td>
<td>Four-Dimensional</td>
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<tr>
<td>AAM</td>
<td>Active Appearance Model</td>
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<td>AAPM</td>
<td>American Association of Physicists in Medicine</td>
</tr>
<tr>
<td>ABCD</td>
<td>Asymmetry, Border, Color, and Differential structures</td>
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<tr>
<td>ACE</td>
<td>Associative Classifier Engine</td>
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<td>ACR</td>
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<td>ACSE</td>
<td>Association Control Service Element</td>
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<td>ADNI</td>
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<td>AE</td>
<td>Application Entity</td>
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<td>AFC</td>
<td>Absolute Fuzzy Connectedness</td>
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<td>American Joint Committee on Cancer</td>
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<td>ALM</td>
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<td>AMN</td>
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<td>ANN</td>
<td>Artificial Neural Network</td>
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<td>AOM</td>
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<td>APD</td>
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<td>API</td>
<td>Application Programming Interface</td>
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<td>ASCF</td>
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<td>BAA</td>
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<td>CASH</td>
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<td>CI</td>
<td>Computational Intelligence; Confidence Interval</td>
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<td>CICE</td>
<td>Cumulative Inverse Consistency Error</td>
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<td>CT Colonography</td>
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</table>
CTE  Cumulative Transitive Error  
CTK  Common Toolkit  
CTR  Cardio-Thoracic Ratio  
CVP  Closest Vessel Projection  
DAG  Directed Acyclic Graph  
DBM  Deformation-Based Morphometry  
DBT  Digital Breast Tomosynthesis  
DCE  Dynamic Contrast-Enhanced  
DCE-MRI  Dynamic Contrast-Enhanced Magnetic Resonance Imaging  
DCMR  DICOM Content Mapping Resource  
DCMTK  OFFIS DICOM ToolKit  
DDSM  Digital Database for Screening Mammography  
DES  Density Emitter Model  
DeVIDE  Delft Visualisation and Image Processing Of Development Environment  
DFT  Discrete Fourier Transform  
DICOM  Digital Imaging and Communications in Medicine  
DICOM SR  DICOM Structured Reporting  
DIMSE  DICOM Message Service Element  
DKFZ  Deutsches Krebsforschungszentrum  
dMRI  Diffusion Magnetic Resonance Imaging  
DNA  Deoxyribonucleic Acid  
DOF  Degree Of Freedom  
DP  Detection Performed  
DPV  Dermatoscopic Point Value  
DR  Digital Radiography  
DSA  Digital Subtraction Angiography  
DSI  Diffusion Spectrum Imaging  
DTI  Diffusion Tensor Imaging  
DTM  Decision Tree Method  
DVD  Digital Versatile Disc  
DWT  Discrete Wavelet Transform  
ECG  Electrocardiography  
EEG  Electroencephalography  
ELM  Epi-Luminescence Microscopy  
EM  Expectation Maximization  
EN  European Norm  
ENT  Ear, Nose, and Throat  
EPI  Echo Planar Imaging  
EXACT  Extraction of Airways from CT  
F-FP-CIT  $^{18}$FluoroPropyl-CarbomethoxyIodophenyl-norTropane
XXXII Acronyms

FA Fractional Anisotropy
FB Filtered Backprojection
FC Fuzzy Connectedness
FDA Food and Drug Administration
FDG $^{18}$F-Fludeoxyglucose
FDI Fédération Dentaire Internationale
FEM Finite Element Model
FFD Free-Form Deformation
FFDM Full-Field Digital Mammography
FID Free Induction Decay
Fiji Fiji Is Just ImageJ
FISH Fluorescent In-Situ Hybridization
FLT $^{18}$F-L-Thymidine
fMRI Functional MRI
FND False Negative Dice
FOV Field-Of-View
FPD False Positive Dice
FROC Free-Response Receiver Operating Characteristic
FSC File Set Creator
FSR File Set Reader
FSU File Set Updater
FWHM Full Width Half Maximum
GA Genetic Algorithms
GC Graph Cut
GDCM Grassroots DICOM Library
GG Generalized Graph
GIF Graphics Interchange Format
GIFT GNU Image Finding Tool
GIMIAS Graphical Interface for Medical Image Analysis and Simulation
GLCM Gray-Level Co-occurrence Matrices
GMM Gaussian Mixture Model
GMP Good Manufacturing Practice
GNU GNU’s Not Unix
GPA Generalized Procrustes Analysis
GPU Graphics Processing Unit
GSPS Grayscale Softcopy Presentation State
GTC Generalized Tanimoto Coefficient
GUI Graphical User Interface
HARAG Hierarchical Attributed Region Adjacency Graph
HARDI High Angular Resolution Diffusion Imaging
HD Hausdorff Distance
HIPAA Health Insurance Portability and Accountability Act
<table>
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<tr>
<th>Acronym</th>
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<tr>
<td>HIS</td>
<td>Hospital Information System; Hue, Intensity, Saturation</td>
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<td>HL7</td>
<td>Health Level Seven</td>
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<td>HRRT</td>
<td>High-Resolution Research Tomograph</td>
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<td>HSV</td>
<td>Hue-Saturation-Value</td>
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