

Jasjit S. Suri  
Aly A. Farag  
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# Deformable Models II

Theory and Biomaterial Applications



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Jasjit S. Suri

Aly A. Farag

# Deformable Models

Theory and Biomaterial Applications



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Jasjit S. Suri  
Eigen LLC  
Grass Valley, CA 95945  
USA  
jsuri@comcast.net

Aly A. Farag  
Professor of Electrical  
and Computer Engineering  
Computer Vision and Image  
Processing Laboratory  
University of Louisville  
Louisville, KY 40292  
USA  
aly.farag@louisville.edu

*Series Editor*

Evangelia Micheli-Tzanakou  
Professor and Chair  
Department of Biomedical Engineering  
Rutgers University  
Piscataway, NJ 08854-8014  
Etzanako@rci.rutgers.edu

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## PREFACE

This volume carries the same flavor as Volume 1 in covering the theory, algorithms, and applications of level sets and deformable models in medical image analysis.

Chapter 1 describes a new approach that integrates the T-Surfaces model and isosurface generation methods within a general framework for segmentation and surface reconstruction in 3D medical images.

Chapter 2 is a study of active contour models in medical image analysis. Various issues with respect to implantation are discussed.

Chapter 3 also deals with active contours with a primary focus on the application and performance of different types of deformable models for analyzing microscopic pathology specimens.

Chapter 4 focuses on construction of the speed function of level sets as applied to segmentation of tagged MR images.

Chapter 5 presents a parallel computational method for 3D image segmentation based on solving the Riemannian mean curvature flow of graphs. The method is applied to segmentation of 3D echocardiographic images.

Chapter 6 provides a review of the level set method and shows the usage of shape models for segmentation of objects in 2D and 3D within a level set framework via regional information.

Chapter 7 also deals with basic application of deformable models to image segmentation. Various applications of the method are presented.

Chapter 8 employs geometric deformable models/level sets to extract the topology of the shape of breast tumors. Using this framework, several features of breast tumors are extracted and subsequently used for classification of breast disease.

Chapter 9 examines various theoretical and algorithmic details of active contour models and their use for image segmentation.

Chapter 10 uses deformable models to devise a segmentation approach for ultrasound images for the study of prostate cancer.

Chapter 11 proposes a novel variational formulation for brain MRI segmentation that uses J-divergence (symmetrized Kullback-Leibler divergence) to measure the dissimilarity between local and global regions.

Chapter 12 examines the use of shape transformations for morphometric analysis in the brain. A shape transformation is a spatial map that adapts an individual's brain anatomy to that of another.

Chapter 13 proposes a nonlinear statistical shape model for level set segmentation. Various algorithmic details are provided to show the effectiveness of the approach.

Chapter 14 uses the level sets methods for structural analysis of brain white and gray matter in normal and dyslexic people.

Chapter 15 describes an approach for estimating left- and right-ventricular deformation from tagged cardiac magnetic resonance imaging using volumetric deformable models constructed from nonuniform rational B-splines (NURBS).

Chapter 16 is a generalization of the methods presented in Chapter 14 with an emphasis on autism. The 3D distance map is used as a shape descriptor of the white matter, and a novel nonrigid registration approach is used to quantify changes in the corpus callosum of normal and autistic individuals.

Overall, the thirty-one chapters in the two volumes provide an elegant cross-section of the theory and application of variational and PDE approaches in medical image analysis. Graduate students and researchers at various levels of familiarity with these techniques will find the two volumes very useful for understanding the theory and algorithmic implementations. In addition, the various case studies provided demonstrate the power of these techniques in clinical applications.

The editors of the two volumes once again express their deep appreciation to the staff at Springer who made this project a fruitful experience.

*Jasjit Suri and Aly Farag  
January 2007*

## CONTRIBUTORS

ALAA E. ABDEL-HAKIM  
Computer Vision and  
Image Processing Laboratory  
Department of Electrical and  
Computer Engineering  
University of Louisville  
Louisville, Kentucky, USA

AMIR A. AMINI  
Cardiovascular Image Analysis Laboratory  
Washington University  
St. Louis, Missouri, USA

SWAPNA BANERJEE  
Department of Electronics and ECE  
Indian Institute of Technology  
Kharagpur, India

MANUEL F. CASANOVA  
Department of Psychiatry and Behavioral  
Sciences  
University of Louisville  
Louisville, Kentucky, USA

RUEY-FENG CHANG  
Department of Computer Science and  
Information Engineering  
Graduate Institute of Networking and  
Multimedia  
National Taiwan University  
Taipei, Taiwan

CHII-JEN CHEN  
Department of Computer Science and  
Information Engineering  
National Chung Cheng University  
Chiayi, Taiwan

WEI-LIANG CHEN  
Department of Computer Science and  
Information Engineering  
National Chung Cheng University  
Chiayi, Taiwan

DANIEL CREMERS  
Department of Computer Science  
University of Bonn  
Bonn, Germany

BIPUL DAS  
Imaging Technology Division  
GE India Technology Centre  
Bangalore, India

CHRISTOS DAVATZIKOS  
Section of Biomedical Image Analysis  
Department of Radiology  
University of Pennsylvania  
Philadelphia, Pennsylvania, USA

MINGYUE DING  
Institute for Pattern Recognition and  
Artificial Intelligence  
Huazhong University of Science and  
Technology  
Wuhan, China

AYMAN EL-BAZ  
Bioengineering Department  
University of Louisville  
Louisville, Kentucky, USA

H. ABD EL-MUNIM  
Computer Vision and Image Processing  
Laboratory  
Department of Electrical and Computer  
Engineering  
University of Louisville  
Louisville, Kentucky, USA

N. YOUSRY EL-ZEHIRY  
Computer Vision and Image Processing  
Laboratory  
Department of Electrical and Computer  
Engineering  
University of Louisville  
Louisville, Kentucky, USA

RACHID FAHMI  
Computer Vision and Image Processing  
Laboratory  
Department of Electrical and Computer  
Engineering  
University of Louisville  
Louisville, Kentucky, USA

ALY A. FARAG  
Computer Vision and Image Processing  
Laboratory  
Department of Electrical and Computer  
Engineering  
University of Louisville  
Louisville, Kentucky, USA

AARON FENSTER  
Robarts Research Institute  
London, Ontario, Canada

DAVID J. FORAN  
Center for Biomedical Imaging  
UMDNJ-Robert Woods Johnson Medical  
School  
Piscataway, New Jersey, USA

GILSON A. GIRALDI  
National Laboratory for Scientific  
Computing  
Petropolis, Brazil

QIANG GUO  
Institute of Image Processing and Pattern  
Recognition  
Shanghai Jiaotong University  
Shanghai, China

PHENG ANN HENG  
Department of Computer Science and  
Engineering  
The Chinese University of Hong Kong  
Hong Kong, China

TIANZI JIANG  
National Laboratory of Pattern Recognition  
Institute of Automation  
Beijing, China

WALTER JIMÉNEZ  
National Laboratory for Scientific  
Computing  
Petropolis, Brazil

HANIF LADAK  
Department of Medical Biophysics  
The University of Western Ontario  
London, Ontario, Canada

XIAOBO LI  
National Laboratory of Pattern Recognition  
Institute of Automation  
Beijing, China

KAROL MIKULA  
Department of Mathematics and  
Descriptive Geometry  
Slovak University of Technology  
Bratislava, Slovakia

ASHRAF MOHAMED  
Section of Biomedical Image Analysis  
Department of Radiology  
University of Pennsylvania  
Philadelphia, Pennsylvania, USA

ANTONIO A.F. OLIVEIRA  
Federal University  
Rio de Janeiro, Brazil

ORIOL PUJOL  
Departamento Matemática Aplicada i  
Análisi  
Universidad de Barcelona  
Barcelona, Spain

YINGGE QU  
Department of Computer Science and  
Engineering  
The Chinese University of Hong Kong  
Hong Kong, China

PETIA RADEVA  
Centre de Visió per Computador  
Universitat Autònoma de Barcelona  
Barcelona, Spain

PAULO S.S. RODRIGUES  
National Laboratory for Scientific  
Computing  
Petropolis, Brazil

MIKAEL ROUSSON  
Department of Imaging and Visualization  
Siemens Corporate Research  
Princeton, New Jersey, USA

ALESSANDRO SARTI  
Dipartimento di Elettronica  
Informatica e Sistemistica  
University of Bologna  
Bologna, Italy

RODRIGO L.S. SILVA  
National Laboratory for Scientific  
Computing  
Petropolis, Brazil

MILAN SONKA  
Department of Electrical and Computer  
Engineering  
The University of Iowa  
Iowa City, Iowa, USA

EDILBERTO STRAUSS  
Federal University  
Rio de Janeiro, Brazil

JASJIT S. SURI  
Biomedical Research Institute  
Idaho State University  
Pocatello, Idaho, USA

CHIA-LING TSAI  
Department of Computer Science and  
Information Engineering  
National Chung Cheng University  
Chiayi, Taiwan

NICHOLAS J. TUSTISON  
Cardiovascular Image Analysis Laboratory  
Washington University  
St. Louis, Missouri, USA

YONGGANG WANG  
Institute of Image Processing and Pattern  
Recognition  
Shanghai Jiaotong University  
Shanghai, China

TIEN-TSIN WONG  
Department of Computer Science and  
Engineering  
The Chinese University of Hong Kong  
Hong Kong, China



FUXING YANG  
Department of Electrical and Computer  
Engineering  
The University of Iowa  
Iowa City, Iowa, USA

LIN YANG  
Department of Electrical and Computer  
Engineering  
Rutgers University  
Piscataway, New Jersey, USA

WANLIN ZHU  
National Laboratory of Pattern Recognition  
Institute of Automation  
Beijing, China

YUN ZHU  
Institute of Image Processing and Pattern  
Recognition  
Shanghai Jiaotong University  
Shanghai, China

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# **T-SURFACES FRAMEWORK FOR OFFSET GENERATION AND SEMIAUTOMATIC 3D SEGMENTATION**

**Gilson A. Giraldi, Rodrigo L.S. Silva,  
Paulo S.S. Rodrigues, and Walter Jiménez**

*National Laboratory for Scientific Computing  
Petropolis, Brazil*

**Edilberto Strauss and Antonio A.F. Oliveira**

*Federal University, Rio de Janeiro, Brazil*

**Jasjit S. Suri**

*Biomedical Research Institute, Idaho State  
University, Pocatello, Idaho, USA*

This chapter describes a new approach that integrates the T-Surfaces model and isosurface generation methods in a general framework for segmentation and surface reconstruction in 3D medical images. Besides, the T-Surfaces model is applied for offset generation in the context of geometry extraction. T-Surfaces is a parametric deformable model based on a triangulation of the image domain, a discrete surface model, and an image threshold. Two types of isosurface generation methods are considered in this work: continuation and marching. The continuation approach is useful during reparameterization of T-Surfaces, while the latter is suitable to initialize the model closer the boundary. First, the T-Surfaces grid and the threshold are used to define a coarser image resolution. This field is thresholded to obtained a 0–1 function that is processed by a marching method to generate

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Address all correspondence to: Gilson A. Giraldi, Laboratório Nacional de Computação Científica, Av. Getulio Vargas, 333, Quitandinha, Petropolis, Brazil, CEP: 25651-075. Phone: +55 24 2233-6088, Fax: +55 24 2231-5595. [gilson@lncc.br](mailto:gilson@lncc.br).



polygonal surfaces whose interior may contain the desired objects. If a polygonal surface involves more than one object, the resolution is increased in that specific region, and the marching procedure is applied again. Next, we apply T-Surfaces to improve the result. If the obtained topology remains incorrect, we enable the user to modify the topology by an interactive method based on the T-Surfaces framework. Finally, we discuss the utility of diffusion methods and implicit deformable models for our approach.

## 1. INTRODUCTION

Deformable Models, which include the popular *snake models* [1] and deformable surfaces [2, 3], are well-known techniques for boundary extraction and tracking in 2D/3D images. Basically, these models can be classified into three categories: parametric, geodesic snakes, and implicit models. The relationships between these categories have been demonstrated in several works [4, 5].

Parametric Deformable Models consist of a curve (or surface) that can dynamically conform to object shapes in response to internal (elastic) and external (image and constraint) forces [6]. In geodesic snakes formulations, the key idea is to construct the evolution of a contour as a geodesic computation. A special metric is proposed (based on the gradient of the image field) to let the state of minimal energy correspond to the desired boundary. This approach allows addressing the parameterization dependence of parametric snake models and can be extended to three dimensions through the theory of minimal surfaces [7, 5]. Implicit models, such as the formulation used in [8], consist of embedding the snake as the zero level set of a higher-dimensional function and to solve the corresponding equation of motion. Such methodologies are best suited for the recovery of objects with unknown topologies.

When considering the three mentioned categories, two aspects are fundamental within the context of the present work: user interaction and topological changes. Parametric models are more suitable for user interaction than the others because they use neither the higher-dimensional formulations of Level Sets nor globally defined features, like the metric in the geodesic approach. However, for most parametric methods the topology of the structures of interest must be known in advance since the mathematical model cannot deal with topological changes without adding extra machinery [9, 10].

Recently, McInerney and Terzopoulos [11, 9, 10] proposed the T-Snakes/T-Surfaces model to add topological capabilities (*splits and merges*) to a parametric model. The resulting method has the power of an implicit approach without requiring a higher-dimensional formulation.

The basic idea is to embed a discrete deformable model within the framework of a simplicial domain decomposition (*triangulation*) of the image domain. In this framework, the reparameterization is based on the projection of the curve/surface over the triangulation and on a *Characteristic Function*, which distinguishes the interior grid nodes of the (closed) curve/surface from the exterior ones. The set