

Contents

Part I Overview and Foundations

1	Introduction	3
1.1	Craniofacial Fractures	3
1.2	State-of-the-Art Virtual Craniofacial Surgery	8
1.3	The Importance of Computer-Assisted Surgical Planning	9
1.4	Organization of the Monograph	12
2	Graph-Theoretic Foundations	15
2.1	Some Basic Terminology	15
2.2	Matchings in Graphs	17
2.3	Isomorphism and Automorphism of Graphs	19
2.4	Network Flows	20
3	A Statistical Primer	25
3.1	Probability	25
3.2	Statistical Inference	28
3.3	Bayesian Statistics	30
3.4	Random Fields, Bayesian Restoration, and Stochastic Relaxation	32

Part II Virtual Craniofacial Reconstruction

4	Virtual Single-Fracture Mandibular Reconstruction	37
4.1	Motivation	37
4.2	Chapter Organization	37
4.3	Related Work and Our Contribution	38
4.4	Image Processing	39
4.4.1	Thresholding	41
4.4.2	Connected Component Labeling	42
4.4.3	Contour Data Extraction	42
4.5	Surface Matching Using Type-0 Constraints	43
4.5.1	Surface Registration Using the ICP Algorithm	43
4.5.2	Registration Using the DARCES Algorithm	45

4.5.3	Registration Using the Hybrid DARCES–ICP Algorithm . .	46
4.6	Improved Surface Matching with Surface Irregularity Modeling . .	47
4.6.1	Curvature-Based Surface Irregularity Estimation	47
4.6.2	Fuzzy Set Theory-Based Surface Irregularity Extraction . .	49
4.6.3	Reward/Penalty Schemes	50
4.7	Improved Surface Matching with Type-1 Constraints	51
4.7.1	Cycle Graph Automorphs as Initial ICP States	52
4.7.2	Selection of the Best Initial State	52
4.7.3	Registration Using the Hybrid Geometric–ICP Algorithm .	54
4.8	Bilateral Symmetry of the Human Mandible	55
4.9	Biomechanical Stability of the Human Mandible	56
4.10	Composite Reconstruction Using MSE, Symmetry, and Stability .	58
4.11	Experimental Results	60
4.12	Conclusion and Future Work	65
5	Virtual Multiple-Fracture Mandibular Reconstruction	71
5.1	Motivation	71
5.2	Chapter Organization	72
5.3	Related Work and Our Contribution	72
5.4	Image Processing	75
5.5	Design of a Score Matrix	76
5.5.1	Modeling Spatial Proximity	78
5.5.2	Modeling Surface Characteristics	78
5.5.3	Score Matrix Elements	79
5.6	Identification of Opposable Fracture Surfaces	80
5.6.1	Combinatorial Nature of the Reconstruction Problem . . .	80
5.6.2	Maximum Weight Graph Matching for Restricting the Reconstruction Options	81
5.7	Pairwise Registration of the Fracture Surfaces	82
5.8	Shape Monitoring of the Reconstructed Mandible	82
5.9	Experimental Results	84
5.10	Conclusion and Future Work	87
Part III Computer-Aided Fracture Detection		
6	Fracture Detection Using Bayesian Inference	91
6.1	Motivation	91
6.2	Chapter Organization	92
6.3	Related Work and Our Contribution	92
6.4	Image Processing	94
6.5	Fracture Point Detection in 2D CT Image Slices	95
6.5.1	Initial Pool of Fracture Points	96
6.5.2	Final Pool of Fracture Points	96
6.6	Stable Fracture Points in a CT Image Sequence	97
6.6.1	The Kalman Filter as a Bayesian Inference Process	97
6.6.2	Concept of Spatial Consistency	98
6.7	Experimental Results	101
6.8	Conclusion and Future Work	107

7	Fracture Detection in an MRF-Based Hierarchical Bayesian Framework	111
7.1	Motivation	111
7.2	Chapter Organization	112
7.3	Related Work and Our Contribution	113
7.4	Coarse Fracture Localization	114
7.4.1	Localization of the Mandible	115
7.4.2	Determination of the Fracture-Containing Symmetric Block Pair(s)	116
7.4.3	Identification of the Fracture-Containing Image Half	117
7.5	Hierarchical Bayesian Restoration Framework	117
7.5.1	Statistical Model	118
7.5.2	Modeling of the Stochastic Degradation Matrix	120
7.6	Experimental Results	122
7.7	Conclusion and Future Work	134
8	Fracture Detection Using Max-Flow Min-Cut	137
8.1	Motivation	137
8.2	Chapter Organization	137
8.3	Related Work and Our Contribution	138
8.4	Max-Flow Min-Cut in a 2D Flow Network	139
8.4.1	Construction of the 2D Flow Network	139
8.4.2	Correctness of the 2D Flow Network Model	141
8.5	Max-Flow Min-Cut in 3D	141
8.5.1	Construction of the 3D Flow Network	141
8.5.2	Correctness of the 3D Flow Network Model	143
8.6	Experimental Results	143
8.7	Conclusion and Future Work	146
Part IV Concluding Remarks		
9	GUI Design and Research Synopsis	151
9.1	Chapter Organization	151
9.2	Design of the Graphical User Interface	151
9.3	Synopsis	154
9.4	Virtual Reconstructive Surgery—An Interdisciplinary Research Perspective	155
9.5	Future Research Directions	156
References		159
Index		167

Computer Vision-Guided Virtual Craniofacial Surgery

A Graph-Theoretic and Statistical Perspective

Chowdhury, A.S.; Bhandarkar, S.M.

2011, XXVI, 166 p., Hardcover

ISBN: 978-0-85729-295-7