

Contents

1	Introduction	1
1.1	Advances in Medical Imaging	1
1.2	Applications of Automatic Detection and Segmentation in Medical Imaging	3
1.3	Previous Work on Automatic Object Detection in Medical Images	6
1.4	Previous Work on Medical Image Segmentation	9
1.5	Marginal Space Learning	11
1.6	Comparison of Marginal Space Learning and Full Space Learning for 2D Problems	12
1.7	Constrained Marginal Space Learning	12
1.8	Marginal Space Learning for Nonrigid Object Detection	14
1.8.1	Optimal Mean Shape	14
1.8.2	Direct Estimation of Nonrigid Deformation Parameters	15
1.9	Other Extensions of Marginal Space Learning	16
1.10	Nonrigid Object Segmentation	17
1.11	Applications of Marginal Space Learning	18
1.12	Organization of this Book	19
	References	19
2	Marginal Space Learning	25
2.1	Introduction	25
2.2	3D Object Detection Using Marginal Space Learning	27
2.2.1	Derivation of Object Pose Ground Truth From Mesh	27
2.2.2	Principle of Marginal Space Learning	29
2.2.3	Training of Position Estimator	32
2.2.4	Training of Position-Orientation Estimator	34
2.2.5	Training of Position-Orientation-Scale Estimator	35
2.2.6	Aggregation of Pose Candidates	36
2.2.7	Object Detection in Unseen Volume	36

2.3	3D Image Features	37
2.3.1	3D Haar Wavelet Features	38
2.3.2	Steerable Features	41
2.4	Classifiers	43
2.4.1	Probabilistic Boosting-Tree	44
2.4.2	Combining Classifier Cascade and Tree	47
2.5	Experiments on Heart Chamber Detection in CT Volumes	49
2.6	Direct Estimation of Nonrigid Deformation Parameters	54
2.6.1	Nonrigid Marginal Space Learning	54
2.6.2	Experiments on Liver Detection in 3D CT Volumes	56
2.7	Theoretical Foundations of Marginal Space Learning	58
2.7.1	Relation to Shortest Path Computation	58
2.7.2	Relation to Particle Filtering	63
2.8	Conclusions	63
	References	63
3	Comparison of Marginal Space Learning and Full Space Learning in 2D	67
3.1	Introduction	67
3.2	Marginal Space Learning for 2D Object Detection	68
3.2.1	Training of Position Estimator	70
3.2.2	Training of Position-Orientation Estimator	70
3.2.3	Training of Position-Orientation-Scale Estimator	71
3.2.4	Object Detection in Unseen Images	72
3.3	Full Space Learning for 2D Object Detection	72
3.4	Performance Comparison Experiment for MSL and FSL Detection	74
3.5	Conclusions	76
	References	77
4	Constrained Marginal Space Learning	79
4.1	Introduction	79
4.2	3D Orientation	80
4.2.1	Representation with Euler Angles	81
4.2.2	Representation with Quaternions	83
4.2.3	Uniform Sampling of 3D Orientation Space	85
4.2.4	Mean Orientation	86
4.3	Constrained Search Space for MSL	87
4.3.1	Constrained Space for Object Position	87
4.3.2	Constrained Space for Orientation	89
4.3.3	Constrained Space for Scale	91
4.4	Experiments on Constrained Marginal Space Learning	93
4.4.1	Liver Detection in CT Volumes	93
4.4.2	Left Ventricle Detection in CT Volumes	95
4.4.3	Left Ventricle Detection in Ultrasound Volumes	98

4.5	Conclusions	100
	References	100
5	Part-Based Object Detection and Segmentation.....	103
5.1	Introduction	103
5.2	Part-Based Left Atrium Detection and Segmentation in C-arm CT	105
5.2.1	Part-Based Left Atrium Model	107
5.2.2	Constrained Detection of Left Atrium Parts	109
5.2.3	Experiments on Left Atrium Segmentation in C-arm CT	111
5.3	Ranking Based Multi-Detector Aggregation for Left Ventricle Detection in 2D MRI	115
5.3.1	Part-Based Left Ventricle Model	116
5.3.2	Ranking Features.....	117
5.3.3	Ranking-Based Aggregation	121
5.3.4	Experiments on Ranking-Based Aggregation	122
5.4	Part-Based Aorta Detection and Segmentation from C-arm CT	124
5.4.1	Part-Based Aorta Segmentation	125
5.4.2	Evaluation of Aorta Segmentation	131
5.5	Conclusions	131
	References	133
6	Optimal Mean Shape for Nonrigid Object Detection and Segmentation	137
6.1	Introduction	137
6.2	Heuristic Mean Shape Using a Bounding Box Based Approach	138
6.3	Optimal Mean Shape for Nonrigid Shape Initialization	139
6.3.1	Procrustes Optimization for Mean Shape and Pose Parameters	139
6.3.2	Procrustes Analysis Under Isotropic Similarity Transformation	140
6.3.3	Procrustes Analysis Under Anisotropic Similarity Transformation	142
6.3.4	Generalized Procrustes Analysis to Align a Group of Shapes Under Anisotropic Similarity Transformation	144
6.4	Application to Aortic Valve Landmark Detection.....	145
6.4.1	Aortic Valve Landmark Detection for Transcatheter Aortic Valve Implantation.....	146
6.4.2	Unique Mean Shape for Aortic Valve Landmarks.....	147
6.4.3	Experiments on Aortic Valve Landmark Detection	148
6.5	Application to Whole-Heart Segmentation	150
6.5.1	Whole-Heart Segmentation.....	150
6.5.2	Experiments on Whole-Heart Segmentation.....	153

6.6	Conclusions	156
	References	156
7	Nonrigid Object Segmentation: Application to Four-Chamber Heart Segmentation	159
7.1	Introduction	159
7.2	Related Work on Heart Modeling and Segmentation	161
7.2.1	Heart Modeling	161
7.2.2	Heart Segmentation	162
7.3	Four-Chamber Heart Modeling	162
7.3.1	Left Ventricle and Left Atrium Models	162
7.3.2	Right Ventricle and Right Atrium Models	163
7.3.3	Establishing Point Correspondence	166
7.3.4	Statistical Shape Model	168
7.4	Nonrigid Deformation Estimation for Heart Chambers	173
7.4.1	Learning Based Boundary Detector	174
7.4.2	TPS Deformation Model	175
7.4.3	Boundary Delineation	177
7.5	Optimal Smooth Surface for Left Ventricle Endocardium Segmentation	179
7.5.1	Clinical Requirements	179
7.5.2	Left Ventricle Blood Pool Extraction	181
7.5.3	Optimization Based Surface Smoothing	182
7.5.4	Comparison with Previous Work	185
7.6	Experiments on Four-Chamber Heart Segmentation	186
7.6.1	Data Sets	186
7.6.2	Experiments on Boundary Delineation	187
7.6.3	Heart Chamber Tracking	193
7.7	Conclusions	195
	References	196
8	Applications of Marginal Space Learning in Medical Imaging	199
8.1	Introduction	199
8.2	Detection of Devices and Anatomical Structures	200
8.2.1	Ultrasound Transducer Detection in Fluoroscopy	200
8.2.2	Balloon Marker Detection in Fluoroscopy for Stent Enhancement	201
8.2.3	Pigtail Catheter Tip Detection in Fluoroscopy	203
8.2.4	Catheter Detection and Tracking in Fluoroscopy	204
8.2.5	Landmark Detection and Scan Range Delimitation in Topogram	205
8.2.6	Left and Right Ventricle Detection in 2D MRI	207
8.2.7	Cardiac Measurements from 2D Ultrasound	210
8.2.8	Mid-Sagittal Plane Detection in 3D MRI	211
8.2.9	Intervertebral Disk Detection in 3D MRI/CT	212
8.2.10	Osteolytic Spinal Bone Lesion Detection in CT	214

8.2.11	Lymph Node Detection in CT	216
8.2.12	Ileocecal Valve Detection in CT.....	217
8.2.13	Aortic Valve Landmark Detection in C-arm CT.....	218
8.2.14	Coronary Ostium Detection in CT	220
8.2.15	Rib Detection in CT	221
8.2.16	Standard Echocardiographic Plane Detection in 3D Ultrasound	222
8.2.17	Fetal Brain Anatomical Structure Detection in 3D Ultrasound	224
8.3	Detection and Segmentation of Anatomical Structures	226
8.3.1	Heart Chamber Segmentation in CT	226
8.3.2	Left and Right Ventricle Segmentation and Tracking in 3D MRI.....	228
8.3.3	Left Ventricle Segmentation and Tracking in 3D Ultrasound	229
8.3.4	Whole-Heart Segmentation in CT	231
8.3.5	Segmentation of Left Atrium, Pulmonary Vein, and Left Atrial Appendage in C-arm CT	233
8.3.6	Aorta Segmentation in CT/C-arm CT.....	234
8.3.7	Heart Valve Segmentation in 3D Ultrasound and CT	236
8.3.8	Pulmonary Artery Trunk Segmentation in CT and MRI	238
8.3.9	Esophagus Segmentation in CT	239
8.3.10	Liver Segmentation in CT	241
8.3.11	Segmentation of Prostate, Bladder, and Rectum in CT and MRI	242
8.3.12	Lung Segmentation in CT	243
8.3.13	Wrist Bone Segmentation in 3D MRI.....	245
8.3.14	Ovarian Follicle Detection/Segmentation in 3D Ultrasound	246
8.3.15	Fetal Face Detection and Segmentation in 3D Ultrasound	247
8.3.16	Fetal Limb Segmentation in 3D Ultrasound	248
8.3.17	Multiple Subcortical Brain Structure Segmentation in 3D MRI	249
8.3.18	Multiple Organ Segmentation in Full Body CT	250
8.4	Conclusions	251
	References	252
9	Conclusions and Future Work	257
9.1	Summary of Contributions	257
9.2	Future Work	259
	Index	263

Marginal Space Learning for Medical Image Analysis
Efficient Detection and Segmentation of Anatomical
Structures

Zheng, Y.; Comaniciu, D.

2014, XX, 268 p. 122 illus., 58 illus. in color., Hardcover

ISBN: 978-1-4939-0599-7