Contents

List of figures v

List of tables vii

1 Introduction 1

1.1 The Centerline Detection Problem: Definition, Applications and Challenges 3

1.1.1 Neurite Tracing: The Data Size Challenge 5

1.1.2 Blood Vessel Reconstruction: Localization Accuracy 6

1.1.3 Road Detection: The Importance of Context 6

1.1.4 Membrane Detection: Junctions and Topological Relevant Features . 7

1.2 Contributions 8

1.3 Thesis Outline 11

2 Related Work 13

2.1 Hand-Crafted Filters for Centerline Detection 16

2.2 Learning Filters for Centerline Detection 17

2.3 Boundary and Membranes Detection 19

3 Multiscale Centerline Detection by Learning a Scale-Space Distance Transform 23

3.1 Centerline Detection as a Classification Problem 25

3.2 Centerline Detection as a Regression Problem 27

3.3 Multiscale Centerline Detection 31

3.4 Efficient Features for Centerline Detection 33

3.4.1 Multiscale Features 35

3.5 Implementation Details 36

Sironi, Amos Verfasser aut
Multiscale centerline extraction based on regression and projection onto ...

digitalisiert durch
IDS Basel/Bern, im Auftrag der
Schweizerischen Nationalbibliothek

3.6 Experimental Evaluation 39
3.6.1 Datasets and Parameters 39
3.6.2 Evaluation 41

4 Learning Separable Filters **47**
4.1 Related Work on Separable Filter Learning 48
4.2 Learning Centerline Features 49
4.3 Learning Separable Filters 51
4.4 Computational Complexity 54
4.5 Experimental Evaluation 58
4.5.1 Detection of Curvilinear Structures 58
4.5.2 Convolutional Neural Networks 60
4.5.3 Comparison between *SEP-COMB* and *SEP-TD* 64

5 Leveraging Contextual Information for Centerline Detection **67**
5.1 The Importance of Context for Centerline Detection 68
5.2 Adding Spatial Context 70
5.3 Adding Scale-Space Context 72
5.4 Scale-Space Context-Aware Features 73
5.5 Experimental Evaluation 75
5.5.1 Pixel-Wise Evaluation 75
5.5.2 Tracing Evaluation 79
5.5.3 Automated Reconstruction 81
5.6 Boundary Detection 83

6 Efficient Projection onto the Set of Elongated Structures for Accurate Extraction **89**
6.1 Topological Inconsistency of Pixel-Wise Approaches 90
6.2 Efficient Projection using Patch-Wise Nearest Neighbors 92
6.2.1 Improving the Distance Function by Patch-Wise Projection 94
6.3 Projection onto the Set of Elongated Structures 96
6.3.1 Equivalence of $\Pi_{D \to N}(X)$ and $\Pi_N(X)$ 96
6.3.2 Synthetic Example 98
6.4 Implementation Details 105
6.4.1 Multi-Resolution Approach 105
6.4.2 Efficient Implementation for Sparse Score Maps 106
6.5 Experimental Evaluation 107
6.5.1 Centerline Detection 107
6.5.2 Vessel Segmentation 111

6.5.3 Membrane Segmentation 112
6.5.4 Boundary Detection 115

7 Conclusion **119**

A Proof of Theorems **125**
A.1 Equivalence of $\Pi_{D\to N}(X)$ and $\Pi_N(X)$ 125
A.1.1 Notation 126
A.1.2 Exact Projection 128
A.1.3 Approximated Projection 131

Bibliography **150**