

Contents

Acknowledgements	vii
Notation and abbreviations	ix
1 Introduction	11
1.1 Motivation	11
1.2 Work goals	13
1.3 Thesis	15
1.4 State of art	15
1.4.1 Introduction	15
1.4.2 Segmentation	16
1.4.3 Classification	17
1.4.4 Classification on multiple data sets	19
1.4.5 Features fusion	20
1.5 List of the most important achievements	21
1.5.1 General diagram of the classification process	21
1.5.2 Using segmentation to normalize images	21
1.5.3 Deep feature acquisition and feature fusion	21
1.5.4 Selection of diagnostically relevant features	22
1.6 Dissertation structure	23
2 Medical imaging	24
2.1 Digital image	24
2.2 Datasets	26
2.2.1 A set of cytological images from the Hospital in Zielona Góra	26
2.2.2 BreakHis histopathology image set	26
2.2.3 Data merging	27
2.3 Pre-processing of digital images	30
2.4 Summary	31
3 Image normalization by segmentation	32
3.1 Introduction	32
3.2 Segmentation using a convolutional neural network	32
3.3 Hybrid segmentation system	34
3.4 Evaluation methods	36
3.5 Verification of the accuracy of the hybrid segmentation method . .	38
3.5.1 Implementation of a hybrid segmentation method	38
3.5.2 Results of segmentation of cell nuclei	42
3.6 Summary	48

4 Comprehensive classification system	53
4.1 Introduction	53
4.2 Manual feature extraction	53
4.3 Deep feature extraction	56
4.3.1 Machine learning	56
4.3.2 Elements of artificial neural networks	57
4.3.3 Convolutional neural networks	57
4.3.4 Team learning methods	61
4.4 Dimensionality reduction	63
4.4.1 Extraction and construction of new features	63
4.4.2 Feature selection	64
4.4.3 Stochastic feature selection	67
4.5 Master classifiers	70
4.6 Classification with an artificial convolutional neural network	71
4.7 Evaluation methods	71
4.8 Results	72
4.8.1 Scheme of the empirical research conducted	72
4.8.2 Deep networks	72
4.8.3 Developed classification system	86
4.9 Discussion	104
4.10 Summary	106
5 Summary	107
5.1 Conclusions	107
5.2 Analysis of results and contribution to the development of the discipline	108
5.3 Further work	109
A Results of additional experiments	110
B Hardware and software configuration	116
C U-Net structure for segmentation	117
Bibliography	119
Index	128
List of figures	129
List of tables	131
D Streszczenie	
Streszczenie	133