

Contents

Acknowledgements	v
Abstract(English/Français)	vii
List of figures	xv
List of tables	xviii
I Introduction	1
1 General introduction	3
1.1 Motivations	3
1.2 What is novelty detection about ?	4
1.3 Thesis objectives	7
1.4 Thesis contributions	8
2 Introduction to remote sensing	11
2.1 A brief history of remote sensing	11
2.2 Remote sensing of the Earth by satellites/airborne platforms	12
2.2.1 Optical remote sensing	13
2.2.2 Sensors characteristics	15
2.3 Remote sensing classification and change detection	18
2.3.1 Change detection in remote sensing	19
2.3.2 Classification in remote sensing	21
2.4 Summary	23
3 Introduction to machine learning	25
3.1 Learning from data	25
3.2 Generalization	28
3.3 Learning paradigms	33
3.3.1 Supervised learning	33
3.3.2 Unsupervised learning	34
3.3.3 Semi-Supervised learning	37
	xi

Contents

3.4	Learning with kernels	38
3.4.1	The kernel trick	39
3.4.2	Mercer kernels	40
3.4.3	Reproducing kernel Hilbert spaces (RKHS)	42
3.4.4	Support Vector Machines (SVM)	43
3.4.5	Cost-Sensitive SVM (CS-SVM)	46
3.5	Summary	47
4	Novelty detection in machine learning	49
4.1	The novelty, the outlier and the anomaly	49
4.2	Novelty detection in applications	51
4.3	General formulation	52
4.3.1	Supervised novelty detection	54
4.3.2	Unsupervised novelty detection	54
4.3.3	Semi-supervised novelty detection	54
4.4	State-of-the-art in novelty detection	55
4.4.1	Density estimation approaches	55
4.4.2	Reconstruction-based approaches	58
4.4.3	Support Vector Machines and boundary approaches	59
4.4.4	Neural network approaches	63
4.4.5	Information theoretic approaches	64
4.5	Summary	64
II	Novelty detection in clusters	65
5	Background	67
5.1	Data made of overlapping clusters	67
5.2	Support Vector Clustering	68
5.2.1	Describing cluster boundaries with support vectors	68
5.2.2	Cluster assignment	69
5.3	Entire solution path algorithms	70
5.3.1	OC-SVM entire solution path	70
5.3.2	CS-SVM entire solution path	72
5.4	Nested decision boundaries	73
5.4.1	Nested OC-SVM solution path	73
5.4.2	Nested CS-SVM solution path	74
5.5	Summary	76
6	Unsupervised change detection via hierarchical clustering	77
6.1	Clustering and outlier hierarchy	77
6.2	Hierarchical clustering algorithms	79
6.2.1	Hierarchical support vector clustering	79

6.2.2	Hierarchical Gaussian process clustering	80
6.2.3	Cluster assignment from hierarchical adjacency matrices	81
6.3	Validity measure for hierarchical clustering	82
6.4	Cluster merging criteria	85
6.4.1	Outlier dispersion as merging mechanism	85
6.4.2	Penalizing different core sizes	87
6.4.3	Setting the merging level	88
6.4.4	Computational considerations	88
6.5	Experiments	89
6.5.1	Experimental setup	89
6.5.2	Results	90
6.6	Conclusions	92
7	Semi-supervised novelty detection via SVM entire solution path	95
7.1	Detecting unknown changes under limited supervision	95
7.2	Semi-supervised novelty detection as a two-class problem	97
7.3	Unsupervised parameter selection based on the cluster assumption	98
7.4	Computational complexity	100
7.5	Experiments	101
7.5.1	Experimental setup	102
7.5.2	Numerical results	106
7.5.3	Free parameters sensitivity	108
7.5.4	Algorithms runtime and convergence analysis	110
7.6	Conclusions	110
III	Novelty detection in manifolds	113
8	Background	115
8.1	High dimensional data on manifolds	115
8.2	Linear subspaces	118
8.2.1	Sparse Subspace Clustering	119
8.2.2	Low-Rank Subspace Clustering	120
8.2.3	Sparse and low-rank Subspace Clustering	122
8.3	Non-linear subspaces	123
8.4	Summary	124
9	Unsupervised classification	
	via non-linear low-rank and sparse subspace representation	125
9.1	Non-linear subspace representation	125
9.1.1	Kernel Low-Rank and Sparse Subspace Clustering (KLRSSC)	126
9.1.2	Kernel Low-Rank Subspace Clustering (KLRSC): $\lambda \rightarrow 0$	129
9.1.3	Kernel Sparse Subspace Clustering (KSSC): $\lambda \rightarrow \infty$	130

Contents

9.1.4	Handling noise	131
9.1.5	Handling outliers	132
9.1.6	Handling missing entries	132
9.2	Scalable clustering	132
9.2.1	Collaborative representation	132
9.2.2	About scalability	133
9.3	Parameters and model selection	134
9.4	Subspace independence measures	135
9.4.1	Linear subspaces	135
9.4.2	Non-linear subspaces	136
9.5	Experiments	137
9.5.1	Experiment 1: Face and object clustering	137
9.5.2	Experiment 2: Unsupervised hyperspectral image classification	146
9.6	Conclusions	152
10	Semi-supervised one-class classification via graphs	153
10.1	Introduction	153
10.2	One-class label propagation	154
10.3	One-class constrained spectral clustering	155
10.3.1	Spectral orthogonal subspace projection	156
10.3.2	Spectral learning	157
10.3.3	Constrained spectral clustering	157
10.4	One-class classifier with graph-based regularization	159
10.5	Experiments	159
10.5.1	Experimental setup	159
10.5.2	Results	160
10.6	Conclusions	163
IV	Conclusions	167
Conclusions		169
	Towards more realistic detection approaches	169
	Contributions	170
	Further perspectives	171
A	Appendix A	173
A.1	Accuracy evaluation metrics	173
B	Appendix B	177
B.1	Landsat	177
B.1.1	Bastrop fires	177
B.1.2	Gloucester floods	179

B.2	ROSI	180
B.2.1	Pavia DFC	180
B.2.2	Pavia center	181
B.3	Faces and objects databases	182
C	Appendix C	185
C.1	Additional face & object clustering results	185
	Bibliography	190
	Curriculum Vitae	215