

Bayesian Visual Surveillance

From Object Detection to Distributed Cameras

ACADEMISH PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Universiteit van Amsterdam
op gezag van de Rector Magnificus
prof. mr. P.F. van der Heijden
ten overstaan van een door het college voor promoties ingestelde
commissie, in het openbaar te verdedigen in de Aula der Universiteit
op dinsdag 17 januari 2006, te 12:00 uur

door
Wojciech Piotr Zajdel
geboren te Kraków, Polen

CONTENTS

1	Introduction	1
2	Probabilistic Graphical Models	7
2.1	Probabilistic Reasoning	7
2.1.1	Motivation	7
2.1.2	Background	8
2.2	Graphical models	9
2.2.1	Undirected graphical models	11
2.2.2	Directed graphical models	12
2.2.3	Factor Graphs	16
2.3	Inference methods	17
2.3.1	Overview	17
2.3.2	Message-passing algorithms	19
2.4	Learning methods	26
2.4.1	Overview	26
2.4.2	Frequentist learning	26
2.4.3	Bayesian learning	28
2.5	Summary	29
3	Sequential data association for multi-object tracking with sparse cameras	31
3.1	Introduction	31
3.2	Overview	33
3.3	Probabilistic generative model	35
3.4	Associating observations	38
3.4.1	EM for a tractable structure space	39
3.4.2	Approximate EM for an intractable structure space	40
3.4.3	Relation to other methods	42
3.5	Experiments	42
3.6	Conclusions	48
3.7	Appendix	50

4 A Hybrid Graphical Model for Online Multicamera Tracking	53
4.1 Introduction	53
4.2 Probabilistic Generative Model	54
4.2.1 Model for a single observation	55
4.2.2 Prior density for states	57
4.2.3 Model for a sequence of observations	57
4.2.4 Graphical representation	59
4.3 Online tracking	59
4.3.1 Probabilistic filtering	60
4.3.2 Approximate filtering	61
4.3.3 Algorithm	61
4.3.4 Limiting memory and computational costs	63
4.4 Experiments	64
4.5 Discussion	71
4.6 Conclusions	74
4.7 Appendix	74
5 A model of spatial pixel correlations for background segmentation	79
5.1 Introduction	79
5.2 Probabilistic modeling of pixel correlations	81
5.2.1 Probabilistic framework	82
5.2.2 Markov Random Fields	83
5.3 Clipped factor analysis model	84
5.3.1 Inference	86
5.3.2 Learning	89
5.4 Experiments	90
5.5 Conclusions	98
5.6 Appendix	100
6 Conclusions	107
6.1 Summary of conclusions	107
6.2 Future research	109
Summary	111
Samenvatting	115
Bibliography	119
Acknowledgments	127