

Contents

Acknowledgments	iii
Abstract	v
Abbreviations and symbols	xi
1 Introduction	1
2 Medical Background	5
2.1 Human Anatomy and Physiology	5
2.1.1 The Cardiac System	5
2.1.2 The Respiratory System	11
2.1.3 The Skin	12
2.2 The Geriatric Patient	13
2.2.1 Introduction to the Ageing Process and Geriatric Patient	13
2.2.2 Frailty – The Central Geriatric Syndrome	16
2.2.3 Early Geriatric Rehabilitation	21
2.2.4 The Geriatric Assessment	23
3 Methodical Background	29
3.1 Non-Contact Vital Signs Monitoring Techniques	29
3.1.1 Optical Techniques	29
3.1.2 Electromagnetic Techniques	37
3.2 Sensor Fusion	42
3.2.1 Introduction to Sensor Fusion	42
3.2.2 Sensor Fusion in Vital Signs Monitoring	43
3.3 The Classification Problem	44
3.4 Statistical Methods and Evaluation Metrics	49
4 Camera-based Vital Signs Monitoring in Geriatric Patients	53
4.1 Design and Implementation of the Clinical Study	53
4.1.1 Recruitment of Participants	54
4.1.2 Experimental Setup	55
4.2 Extraction of Physiological Signals from Video Data	58
4.2.1 Cardiac Signals	59
4.2.2 Respiratory Signals	60
4.2.3 Reference Data	63
4.3 Binary Classification of Physiological Signals	63

4.4	Measurement of Vital Signs	65
4.4.1	Heart Rate	66
4.4.2	Heart Rate Variability	71
4.4.3	Respiratory Rate	73
4.5	Summary	82
5	Bedside Hyper-Modal Vital Signs Sensor Fusion	83
5.1	System Overview	83
5.1.1	Bed-Integrated Multi-Modal Vital Signs Sensor System	84
5.1.2	Time Synchronisation and Integration of the Multi-Spectral Camera System	90
5.2	Laboratory Study	92
5.2.1	Objectives and Hypotheses	92
5.2.2	Experimental Setup	93
5.3	Measurement of Vital Signs	97
5.3.1	Data Pre-Processing	97
5.3.2	Measurement of Heart Rate and Heart Rate Variability	99
5.3.3	Measurement of Respiratory Rate	102
6	Results and Discussion	105
6.1	Camera-based Monitoring for Geriatric Patients	105
6.1.1	Characterisation of the Study Population	105
6.1.2	Classifier Analysis	107
6.1.3	Measurement of Heart Rate	111
6.1.4	Measurement of Heart Rate Variability	113
6.1.5	Influence of Frailty and Early Geriatric Rehabilitation on Heart Rate Variability	116
6.1.6	Measurement of Respiratory Rate	117
6.2	Bedside Hyper-Modal Sensor Fusion	120
6.2.1	Measurement of Heart Rate	120
6.2.2	Measurement of Heart Rate Variability	123
6.2.3	Measurement of Respiratory Rate	125
6.3	Discussion and Summary	128
6.3.1	Camera-based Monitoring in Geriatric Patients	128
6.3.2	Influence of Frailty and Early Geriatric Rehabilitation on Heart Rate Variability	131
6.3.3	Bed-Integrated Hyper-Modal Sensor Fusion	133
7	Conclusion and Future Perspectives	137
A	Appendix	143

B Curriculum Vitae	163
C Publications	165
Bibliography	169