

Contents

Foreword	v
Acknowledgements	vii
Abstract	ix
Kurzfassung	xi
Contents	xiii
List of Figures	xvii
List of Tables.....	xxiii
1. Introduction.....	1
1.1 Augmented reality	2
1.2 Ubiquitous computing	4
1.3 Problem statement.....	6
1.4 Hypotheses.....	7
1.5 Contribution	8
1.6 Collaboration statement.....	10
1.7 Organization.....	16
2. Background and related work	19
2.1 Augmented reality displays.....	19
2.2 Mobile augmented reality.....	20
2.3 Geospatial models	24
2.4 Pose tracking.....	28
2.5 Discussion.....	31
3. Requirements	33
3.1 Sensor reference frame	33
3.2 Data reference frame	34
3.3 Global reference frame.....	35
3.4 Augmented reality models.....	36
3.5 System design considerations	37
4. Interactive geospatial models for augmented reality	39
4.1 Manual surveying	39
4.2 Semi-automatic surveying.....	44

4.3	Example application	49
4.4	Transcoding pipeline.....	53
4.4.1	Transcoding process	53
4.4.2	Anatomy of the geospatial infrastructure	57
4.4.3	Transcoding trade-off analysis	62
4.4.4	Limitations.....	65
4.5	Discussion.....	65
5.	Hardware setups for augmented reality.....	67
5.1	Requirements	68
5.2	UMPC-based setups.....	69
5.3	Vesp'R setup	71
5.4	Evaluation of Vesp'R setup	72
5.4.1	Mobile computing developers	73
5.4.2	Mixed user group.....	75
5.4.3	Field worker interview	77
5.4.4	Management level feedback.....	79
5.4.5	Evaluation summary	79
5.5	POMAR-3D setup.....	80
5.6	Tablet PC-based setup	83
5.7	Discussion.....	84
6.	Pose tracking	85
6.1	Global pose estimation using multi-sensor fusion	85
6.2	Position tracking.....	87
6.3	Orientation tracking	89
6.3.1	Gyroscope measurement model	90
6.3.2	Magnetometer measurement model	91
6.3.3	Accelerometer measurement model.....	91
6.4	Visual tracking approach.....	92
6.5	Fusion of attitude with visual tracking	94
6.6	Position using differential GPS.....	97
6.7	Position using real-time kinematic GPS.....	100
6.8	Attitude Kalman filter	106
6.9	Visual tracking	110

6.10	Combination of attitude with visual tracking	112
6.11	North-centered orientation tracking	114
6.11.1	Orientation estimation and sensor fusion	115
6.11.2	Kalman filter setup	117
6.11.3	Results	118
6.12	Discussion	127
7.	Applications – AR visualization and interaction in civil engineering	129
7.1	Concept	130
7.1.1	Inspection toolset	133
7.1.2	Excavation tool	134
7.1.3	Metadata Querying tool	135
7.1.4	Filtering tool	136
7.2	Snapshot tool	136
7.3	Interactive redlining toolset	136
7.3.1	Annotating the geospatial model	137
7.3.2	Surveying in the geospatial model	138
7.3.3	Interactive validation of object placement	138
7.4	Verification toolset	139
7.4.1	Visualization of abstract information	139
7.4.2	Verification of abstract information	140
7.5	Evaluation results	140
7.5.1	Evaluation procedure	142
7.5.2	Digital terrain model	143
7.5.3	Virtual redlining	143
7.5.4	Verification of abstract information	146
7.6	Role of AR in field information systems	146
7.7	Discussion	149
8.	Conclusions	151
8.1	Reflection	151
8.2	Road map	154
	Appendix	155
	Bibliography	163