Contents

Al	bstract			
Zu	Zusammenfassung			
$A \epsilon$	cknowledgments	xi		
$A \epsilon$	cronyms	xvii		
1	Introduction	1		
	1.1 Motivation	3		
	1.2 Focused research problems	6		
	1.3 Structure of the thesis	8		
2	Digitalisation concepts			
	2.1 Smart Systems	11		
	2.2 3D information modelling: BIM and 3D GIS	12		



	2.3	Intern	net of Things (IoT) and digital twin	15	
	2.4	Game	ful Design	16	
	2.5	Vir t u a	al Reality and immersive technologies	18	
3	Immersive 3D planning of total station networks				
	3.1	Brief history: 2D network design			
	3.2	State of the art: 2.5D network design			
	3.3	Challenges for the design of monitoring installations			
	3.4	Motivation for an object orientated 3D approach			
	3.5	3.5 Software realisation: VRsurv			
		3.5.1	Design with Unity	37	
		3.5.2	Data Templates	39	
		3.5.3	Usage of Virtual Reality	40	
		3.5.4	Related work: 3D instrument simulation	43	
	3.6	Imple	mented 3D Quality checks in VRsurv	44	
		3.6.1	Collision control	44	
		3.6.2	Set-up stability due to direct sun exposure	47	
		3.6.3	Orientation of prisms	50	
		3.6.4	Interferences caused by adjacent prisms	55	
		3.6.5	Visualisation of confidence ellipsoids	60	
	3.7	-		62	
		3.7.1	Task description and requirements	62	
		3.7.2	Console design and placement of the total sta-	•	
			tion	64	
		3.7.3	Prism configuration and automatic target aim-		
			ing	66	
		3.7.4	Results of the feasibility study	67	
	3.8	Conclusion		68	
		3.8.1	Improvements	68	
		3.8.2	Limitations	69	
		3.8.3	Future work	70	
4	Sma	rt total	l station monitoring	71	
	4.1	State	of the art: Monitoring with total stations	72	

		4.1.1	Commercial monitoring solutions	72			
		4.1.2	Customised monitoring solutions	74			
	4.2	Challenges for state-of-the-art systems 7					
	4.3	Enhanced total station monitoring for complex sites 76					
	4.4	Smart prism objects 79					
	4.5	Avoidance of local atmospheric disturbances					
		4.5.1	Air-conditioning devices and total station mon	!-			
			itoring	82			
		4.5.2	Atmospheric experiments on the roof of Gra	\boldsymbol{z}			
			University of Technology	83			
		4.5.3	Experimental digital twin application with th	e			
			Unity software	86			
		4.5.4	Outlook: dynamic temperature acquisition with	h			
			mobile platforms	87			
	4.6	Temporary obstruction of the line of sight 8					
	4.7	Conch	usion	91			
		4.7.1	Improvements	91			
		4.7.2	Limitations	93			
		4.7.3	Future work	94			
5	Imm	Immersive data visualisation with Virtual Reality 95					
	5.1	Brief history: from sculptures to 2D displays 9					
	5.2	State	of the art: Conventional 2.5D viewers	98			
	5.3	Challenges for conventional 2.5D viewers 98					
	5.4	Motivation for the usage of Virtual Reality 103					
	5.5	Hardware development of Virtual Reality devices 103					
	5.6	The role of VR applications in engineering geodesy					
		5.6.1	Visualisation of 3D models and point clouds	106			
		5.6.2	Comprehensive multi-dimensional data investi	i–			
			gation	107			
		5.6.3	Digitalisation and data filtering	112			
		5.6.4	Education	114			
	5.7	Outloo	ok: Collaboration	117			
	5.8	Concli	usion	118			

		5.8.1	Improvements	118
		5.8.2	Limitations	119
		5.8.3	Future work	120
6	Summary and Discussion			121
	6.1	Qualit	ty improvement	122
	6.2	Discus	ssion: Connected 3D environments	123
	6.3	Concl	usion (Surveyor 4.0)	125
	6.4	Main	scientific contributions	127