

Contents

1	Introduction	1
1.1	Main Contributions	3
1.2	Chapter Overview	4
2	Background	5
2.1	Radiometry	5
2.2	Radiometric Terms	6
2.3	The Rendering Equation	8
2.4	Inverse Rendering	10
2.5	Interaction of Light with Matter	11
2.5.1	Bidirectional Reflectance Distribution Functions	13
2.5.2	Physical Properties	14
2.6	Reflection Properties	18
2.6.1	Materials	18
2.6.2	Surface Structure	22
2.6.3	Spatial Variation	24
2.6.4	Hierarchy of Detail	25
2.7	Representations of Reflection Properties	26
2.7.1	Tabulated BRDFs	26
2.7.2	Factorization and Spherical Harmonics	26
2.7.3	BRDF Models	27
3	Related Work on 3D Object Acquisition	29
3.1	Acquisition of Textured 3D Models	30
3.1.1	3D Geometry Acquisition	30
3.1.2	Imaging All Visible Surfaces	32
3.1.3	Image-to-Geometry Registration	32
3.1.4	Texture Preparation	34
3.1.5	Warping-Based Techniques	35
3.2	View-Dependent Representations	35
3.2.1	The Plenoptic Function	35

3.2.2	Panoramas and Mosaics	36
3.2.3	View-Dependent Texturing	36
3.2.4	Light Fields	36
3.2.5	Surface Light Fields	38
3.3	Relightable Representations	39
3.3.1	Scene Relighting	39
3.3.2	Bidirectional Texture Functions	40
3.3.3	Reflectance Fields	41
3.4	Measurement of Bidirectional Reflectance Distribution Functions .	42
3.4.1	Gloss	42
3.4.2	Gonioreflectometer	43
3.4.3	Image-Based Measurements of Homogeneous BRDFs	45
3.5	Sparsely Sampled Spatially Varying BRDFs	45
3.6	Normal Maps	46
3.7	Discussion	47
4	Acquisition Setup	51
4.1	The Camera	51
4.1.1	General Requirements	51
4.1.2	The Choice of Camera	52
4.2	3D Scanning Devices	53
4.3	The Lamps	53
4.3.1	Light Source Geometry	53
4.3.2	Photometric Requirements	54
4.3.3	Real Lamps	54
4.4	The Room	55
4.5	Geometric Camera Calibration and Image Rectification	56
4.6	Noise Reduction	57
4.7	Photometric Camera Calibration	58
4.7.1	High Dynamic Range Imaging	58
4.7.2	Color Issues	58
4.8	Conclusion	60
5	Texture Registration	61
5.1	Introduction	61
5.2	Overview / Contributions	62
5.3	Camera Transformation	62
5.4	Similarity Measure	64
5.4.1	Segmentation	65
5.4.2	Silhouette Comparison	65

5.4.3	Blurred Silhouettes	66
5.4.4	Erroneous Pixels	68
5.5	Non-linear Optimization	69
5.5.1	Hierarchical Optimization	70
5.5.2	Generating a Starting Point	70
5.5.3	Optimizing the Field of View	71
5.6	Texture Stitching	71
5.6.1	Single View Processing	71
5.6.2	Combining Multiple Textures	72
5.6.3	Organizing the Texture	74
5.7	Multiple View Registration	74
5.7.1	Texture Comparison	75
5.7.2	Iterative Global Optimization	75
5.8	Results	76
5.9	Conclusions	80
6	BRDF Measurement by Clustering	81
6.1	Introduction	81
6.2	Acquisition	82
6.3	Recovering the Light Source Position	84
6.4	Resampling of Reflectance Values	85
6.4.1	Assembling Lumitexels	86
6.4.2	Discarding Data at Depth Discontinuities	87
6.4.3	Problems With Non-modeled Geometry	89
6.5	BRDF Fitting	89
6.5.1	Lafortune Model	89
6.5.2	Non-Linear Fitting	90
6.6	Clustering	90
6.6.1	Lumitexel Selection	91
6.6.2	Splitting	91
6.6.3	Reclustering	92
6.6.4	Termination of the Splitting Process	93
6.7	Projection	93
6.7.1	Basis BRDFs	95
6.8	Acquiring Normal Maps	96
6.9	Rendering	98
6.10	Results	100
6.11	Conclusions and Future Work	105

7 Acquisition Planning	107
7.1 Introduction	107
7.2 Related Work in Acquisition Planning	109
7.3 Acquisition Loop	111
7.4 One-Pixel Objects	112
7.5 Uncertainty Minimization	114
7.5.1 Maximization	115
7.6 Multi-Pixel Objects	117
7.6.1 Homogeneous vs. Spatially Varying BRDFs	117
7.6.2 Real-World Constraints	118
7.7 Implementation	118
7.7.1 Texture Atlas	118
7.7.2 Visibility and Shadows	119
7.7.3 Derivatives and Matrix Norms	119
7.8 Measurement Results	120
7.9 Conclusion	123
8 Discussion and Conclusion	125
8.1 Summary	125
8.1.1 Texture Registration	125
8.1.2 BRDF Measurement	126
8.1.3 View-Planning	127
8.2 Future Work	127
A Hessian Matrix	129
Bibliography	131