



	Page
1 Introduction	5
1.1 Motivation	5
1.2 Overview	6
2 Design Synthesis	9
2.1 Engineering Design	9
2.2 Computer Aided Design Synthesis	13
2.3 Data Analysis	14
2.3.1 Data Mining	15
2.3.2 Data Mining for Aerodynamic and Structural Design	17
2.4 Passenger Car Design Synthesis	18
2.4.1 Design Representation	18
2.4.2 Computational Fluid Dynamics Simulation	22
2.4.3 Explorative Design with Latin Hyper Cube Sampling	24
2.4.4 Exploitive Design with an Evolution Strategy	25
2.5 Interim Summary	30
3 Meta Design Representation	31
3.1 Unstructured Surface Mesh	31
3.2 Local Surface Differences	33
3.2.1 Vertex Displacement	34
3.2.2 Curvature Disparity	36
3.2.3 Identification of Corresponding Vertices	38
3.3 Data Generation	42
3.4 Quantification and Analysis of Design Variations	45
3.4.1 Relative Mean Vertex Disparity	45
3.4.2 Relative Design Variance	46
3.5 Application to Passenger Car Design	47
3.5.1 Approaching Design Similarities	48
3.5.2 Identifying Weak Deformed Design Spots	49
3.5.3 Evaluating the Course of Design	52
3.6 Interim Summary	54
4 Design Sensitivity Analysis	57
4.1 Sensitivity Estimation	57
4.1.1 Linear Correlation Techniques	59
4.1.2 Mutual Information Based Sensitivity Index	60
4.1.3 Robust Estimation of Mutual Information	63



CONTENTS

4.2	Identification of Sensitive Areas	66
4.2.1	Unsupervised Clustering	67
4.2.2	Measure of Vertex Similarity	69
4.2.3	Automatic Identification of Sensitive Areas	71
4.2.4	Example	72
4.3	Utilizing Sensitivity Information	72
4.4	Application to Passenger Car Design	73
4.4.1	Direction of performance improvement	74
4.4.2	KNN Sensitivities	77
4.4.3	Reliability of Probabilistic Sensitivity Estimates	80
4.4.4	Sensitive Areas	82
4.5	Interim Summary	84
5	Design Concept Retrieval	85
5.1	Definition	85
5.2	Concept Representation	87
5.3	Concept Evaluation	88
5.3.1	Relevance and Interestingness	89
5.3.2	Measure of Utility	90
5.4	Concept Retrieval	94
5.4.1	Decision Tree	94
5.4.2	Self Organizing Maps	97
5.5	Utilizing Information about Design Concepts	102
5.6	Application to Passenger Car Design	103
5.6.1	Tree Induction for Car Concept Retrieval	103
5.6.2	Car Concept Learning with SOMs	107
5.7	Interim Summary	112
6	Interaction Analysis	113
6.1	Design Interaction	113
6.2	Fundamental Information Concepts	115
6.3	Interaction Information	118
6.4	Three-way Interaction	119
6.4.1	Synergy	120
6.4.2	Redundancy	122
6.4.3	Non-Interaction	124
6.4.4	Compensation	125
6.5	Interaction Graphs	126
6.6	Utilizing Interaction Information	128
6.7	Examples	129
6.7.1	Information Normalization	129



6.7.2	Compensation of Redundancy and Synergy	132
6.8	Application to Passenger Car Design	134
6.9	Interim Summary	137
7	Summary and Outlook	139
7.1	Summary	139
7.2	Outlook	141
A	Design Sensitivity Analysis	145
A.1	Direction of performance improvement	145
B	Related Publications	147