

Contents

| | |
|---|----|
| Preface | v |
| 1 Introduction | 1 |
| 1.1 Design Reuse – What and Why | 2 |
| 1.1.1 Types of design reuse | 2 |
| 1.1.2 The importance of design reuse | 3 |
| 1.2 Product Conceptual Design | 6 |
| 1.2.1 Product family design | 8 |
| 1.3 Major Issues in Design Reuse | 10 |
| 1.3.1 Design reuse process | 11 |
| 1.3.2 Product information modeling | 12 |
| 1.3.3 Product information analysis | 13 |
| 1.3.4 Design synthesis | 13 |
| 1.3.5 Solution evaluation | 14 |
| 1.4 Engineering Design Reuse Applications | 15 |
| 1.4.1 Design reuse in software engineering | 15 |
| 1.4.2 Design reuse in mechanical and electro-mechanical engineering | 18 |
| 1.4.3 Design reuse in manufacturing | 20 |
| 1.5 Barriers to Design Reuse | 22 |
| 1.6 Summary | 24 |
| 2 Design Reuse Systems and Enabling Tools | 27 |
| 2.1 Engineering Design Reuse Approaches | 27 |
| 2.1.1 Case-based reasoning | 28 |
| 2.1.2 Catalog-based design | 29 |
| 2.1.3 Modular design | 31 |
| 2.1.4 Adaptable design | 33 |
| 2.1.5 Expert systems | 35 |
| 2.1.6 Innovative design using TRIZ | 37 |
| 2.2 Reasoning in Design Reuse | 38 |
| 2.2.1 Machine learning | 38 |

| | | |
|-------|---|-----|
| 2.2.2 | Data mining | 40 |
| 2.2.3 | Design structure matrix | 41 |
| 2.2.4 | Artificial neural networks | 43 |
| 2.2.5 | Genetic algorithms | 46 |
| 2.2.6 | Agent-based method | 47 |
| 2.3 | Summary | 49 |
| 3 | Product Information Modeling | 51 |
| 3.1 | Data, Information and Knowledge | 51 |
| 3.2 | Information Modeling – State-Of-The-Art Review | 53 |
| 3.2.1 | Content of information model | 53 |
| 3.2.2 | Modeling languages | 58 |
| 3.2.3 | Taxonomies | 61 |
| 3.2.4 | Database system and web-based environment | 63 |
| 3.3 | Function-Based Product Information Model | 66 |
| 3.3.1 | A multiple facet product information model | 66 |
| 3.3.2 | Representation of function using key element vector | 69 |
| 3.3.3 | Function taxonomies | 71 |
| 3.3.4 | An illustrative example | 74 |
| 3.4 | Summary | 78 |
| 4 | Design of Product Platform | 81 |
| 4.1 | Role of Product Platform | 81 |
| 4.2 | Product Platform and Product Family Design | 83 |
| 4.2.1 | A top-down perspective | 84 |
| 4.2.2 | A bottom-up perspective | 85 |
| 4.3 | Computational Tools for Product Architecture Building | 87 |
| 4.3.1 | QFD-based approach | 87 |
| 4.3.2 | DSM-based approach | 88 |
| 4.3.3 | Heuristic and quantitative approaches | 90 |
| 4.4 | Product Architecture Building Using Self-Organizing Map | 91 |
| 4.4.1 | Introduction of SOM | 91 |
| 4.4.2 | Function clustering based on SOM | 94 |
| 4.4.3 | A case study | 99 |
| 4.4.4 | Evaluation of the SOM method | 103 |
| 4.5 | Other Relevant Issues in Product Platform Design | 106 |
| 4.5.1 | Extraction of KCs as performance criteria | 107 |
| 4.5.2 | Formation of component catalog | 109 |
| 4.5.3 | Establishment of mapping route using correlation matrices | 109 |
| 4.6 | Summary | 111 |

| | | |
|-------|---|-----|
| 5 | Optimization in Product Design | 113 |
| 5.1 | Introduction | 113 |
| 5.1.1 | Weighted sum method | 116 |
| 5.1.2 | Goal programming | 117 |
| 5.1.3 | Multi-level programming/rank ordering | 118 |
| 5.1.4 | Genetic algorithms | 118 |
| 5.2 | Automated Design Synthesis | 121 |
| 5.2.1 | Configuration design | 121 |
| 5.2.2 | Design synthesis techniques | 122 |
| 5.3 | Multi-objective Struggle Genetic Algorithm Design Synthesis | 128 |
| 5.3.1 | Problem formulation | 128 |
| 5.3.2 | The MOSGA algorithm | 131 |
| 5.3.3 | Implementation of MOSGA in product configuration design | 133 |
| 5.3.4 | Precautions and limitations | 139 |
| 5.4 | Post-optimal Solution Selection | 140 |
| 5.5 | A Case Study | 142 |
| 5.5.1 | Experience-based design | 144 |
| 5.5.2 | Product design using the design reuse approach | 146 |
| 5.5.3 | Comparison of the two methods | 151 |
| 5.6 | Summary | 151 |
| 6 | Cost Estimation in Product Development | 153 |
| 6.1 | Introduction | 153 |
| 6.2 | Product Development Cost | 155 |
| 6.2.1 | Cost structure | 155 |
| 6.2.2 | Cost modeling techniques | 158 |
| 6.3 | Cost Estimation in Product Family Development | 166 |
| 6.3.1 | Commonality index | 167 |
| 6.4 | An Empirical Cost Model for Design Reuse | 169 |
| 6.4.1 | Fixed cost | 170 |
| 6.4.2 | Development cost | 171 |
| 6.4.3 | Component cost | 171 |
| 6.5 | Summary | 173 |
| 7 | Product Performance Evaluation | 175 |
| 7.1 | Introduction | 175 |
| 7.1.1 | Relating performance to design parameters | 175 |
| 7.1.2 | Aggregating performance criteria | 177 |
| 7.2 | Robust Design | 178 |
| 7.3 | The Information Content Assessment Method | 182 |
| 7.3.1 | Background – information axiom and information content | 183 |
| 7.3.2 | The information content assessment process | 186 |

| | | |
|-------|--|-----|
| 7.3.3 | Establishing system range from existing products | 187 |
| 7.3.4 | Assessing information content | 193 |
| 7.3.5 | Precautions and limitations | 197 |
| 7.3.6 | A case study | 198 |
| 7.4 | Summary | 203 |
| 8 | A Product Family Design Reuse Methodology | 205 |
| 8.1 | Introduction | 205 |
| 8.1.1 | Scale-based approach | 206 |
| 8.1.2 | Model-based approach | 211 |
| 8.1.3 | Graph-based approach | 211 |
| 8.1.4 | Module-based approach | 211 |
| 8.2 | An Integrated Design Reuse Process Model | 212 |
| 8.2.1 | Product information modeling | 213 |
| 8.2.2 | Knowledge extraction | 214 |
| 8.2.3 | Design synthesis and evaluation | 216 |
| 8.3 | A Web-Based Product Family Design Reuse System | 216 |
| 8.4 | Design of Cellular Phone Product Family | 222 |
| 8.4.1 | Settings | 222 |
| 8.4.2 | Results | 226 |
| 8.4.3 | Analysis | 228 |
| 8.5 | Design of TV Receiver Circuits | 229 |
| 8.5.1 | Settings | 229 |
| 8.5.2 | Solution generation and results | 232 |
| 8.5.3 | Comparison | 233 |
| 8.6 | Summary | 234 |
| 9 | Design Reuse for Embodiment and Detailed Design | 237 |
| 9.1 | Introduction | 237 |
| 9.2 | Online Design Reuse System | 239 |
| 9.2.1 | System architecture | 239 |
| 9.2.2 | Product information representation | 241 |
| 9.3 | Embodiment Design | 241 |
| 9.3.1 | Product case retrieval method | 242 |
| 9.3.2 | Optimal search for alternative solution | 247 |
| 9.3.3 | Exhaustive search | 254 |
| 9.3.4 | GA-based search | 255 |
| 9.3.5 | Solution generation in washing machine design | 260 |
| 9.4 | Detailed Design | 263 |
| 9.4.1 | Architecture of the detailed design transformation | 263 |
| 9.4.2 | Feature-based parametric modeling | 265 |
| 9.4.3 | Product family and variant method | 266 |

| | |
|--|-----|
| 9.4.4 Operation of detailed design reuse | 267 |
| 9.4.5 System implementation | 271 |
| 9.5 Summary | 271 |
| Bibliography | 273 |
| Index | 293 |