

---

# Contents

|  |       |
|--|-------|
| <b>Figures</b> .....   | xix   |
| <b>Tables</b> .....  | xxiii |
| <b>1 Introduction</b> .....  | 1     |
| 1.1 Motivation.....  | 1     |
| 1.1.1 Challenges in Manufacturing, Products and Service Engineering..... | 1     |
| 1.1.2 A Vision: Manufacturing in the Twenty- $x^{th}$ Century.....       | 2     |
| 1.1.3 Preparing (the Technology) for the Twenty- $x^{th}$ Century.....   | 2     |
| 1.1.3.1 Thinkable/Conceivable Technologies.....                          | 3     |
| 1.1.3.2 Human Resources and Human-related Technologies.....              | 4     |
| 1.2 Immediate Goals and Working Areas.....                               | 4     |
| 1.2.1 Information and Knowledge.....                                     | 5     |
| 1.2.2 Elaboration of the Curricula of the Future.....                    | 5     |
| <b>2 Modelling Basics</b> .....  | 7     |
| 2.1 Models and Modelling.....  | 7     |
| 2.1.1 Definitions.....   | 8     |
| 2.1.2 Modelling Stages.....  | 13    |
| 2.1.3 Purpose and Objectives of Modelling.....                           | 15    |
| 2.1.3.1 Why are Models Needed.....                                       | 20    |
| 2.1.3.2 How Models Arise.....  | 22    |
| 2.1.3.3 Models and Product Development.....                              | 23    |
| 2.1.3.4 Models of Product Development.....                               | 24    |
| 2.1.4 Some (Unusual) Examples of Models.....                             | 26    |
| 2.1.4.1 Text.....  | 26    |
| 2.1.4.2 Drawings, Sketches and Maps.....                                 | 27    |
| 2.1.4.3 Pictures.....  | 27    |
| 2.1.4.4 Bank Statements.....   | 27    |
| 2.1.4.5 Itemized Phone Bills.....  | 28    |

|          |  |    |
|----------|--|----|
| 2.1.4.6  | Model of a Circle .....  | 28 |
| 2.2      | Model-related Terms and Notions .....  | 29 |
| 2.2.1    | Prototype .....  | 29 |
| 2.2.2    | Archetype .....  | 30 |
| 2.2.3    | Interrelations Among Important Terms within the Product's<br>Lifecycle ..... | 31 |
| 2.2.4    | Process Models .....   | 33 |
| 2.2.4.1  | Ambiguity of the Word “Process” .....  | 33 |
| 2.2.4.2  | Time .....   | 33 |
| 2.2.4.3  | Relations Between Product, Production and Process .....                      | 34 |
| 2.2.4.4  | Simulation and Modelling of Processes .....                                  | 37 |
| 2.3      | Modelling: Classification .....  | 38 |
| 2.4      | Model Traits .....   | 38 |
| 2.4.1    | Definitions .....  | 40 |
| 2.4.1.1  | Compositeness .....  | 40 |
| 2.4.1.2  | Divisibility .....   | 40 |
| 2.4.1.3  | Accuracy .....   | 40 |
| 2.4.1.4  | Actuality .....  | 40 |
| 2.4.1.5  | Adequacy .....   | 41 |
| 2.4.1.6  | Aspect .....   | 41 |
| 2.4.1.7  | Autonomy .....   | 41 |
| 2.4.1.8  | Cardinality .....  | 41 |
| 2.4.1.9  | Changeability .....  | 42 |
| 2.4.1.10 | Compatibility .....  | 42 |
| 2.4.1.11 | Consistency .....  | 43 |
| 2.4.1.12 | Dimensions .....   | 43 |
| 2.4.1.13 | Durability .....   | 43 |
| 2.4.1.14 | Dynamics .....   | 43 |
| 2.4.1.15 | Extensibility .....  | 43 |
| 2.4.1.16 | Flexibility .....  | 43 |
| 2.4.1.17 | Functionality .....  | 44 |
| 2.4.1.18 | Coverage .....   | 45 |
| 2.4.1.19 | Compound Models .....  | 46 |
| 2.4.1.20 | Granularity (Only for Compound Models) .....                                 | 47 |
| 2.4.1.21 | Homogeneity .....  | 48 |
| 2.4.1.22 | Independence .....   | 48 |
| 2.4.1.23 | Intelligence .....   | 48 |
| 2.4.1.24 | Interchangeability .....   | 48 |
| 2.4.1.25 | Openness and Modifiability .....   | 48 |
| 2.4.1.26 | Paradigm .....   | 49 |
| 2.4.1.27 | Platform .....   | 49 |
| 2.4.1.28 | Portability .....  | 49 |
| 2.4.1.29 | Effort for Porting to new Platform .....                                     | 49 |
| 2.4.1.30 | Platform Independence .....  | 50 |
| 2.4.1.31 | Quality .....  | 50 |
| 2.4.1.32 | Reliability .....  | 50 |
| 2.4.1.33 | Reparability .....   | 50 |

|          |  |           |
|----------|--|-----------|
| 2.4.1.34 | Reusability .....  | 50        |
| 2.4.1.35 | Robustness .....   | 51        |
| 2.4.1.36 | Scalability .....  | 52        |
| 2.4.1.37 | Size .....   | 52        |
| 2.4.1.38 | Time Dependency .....  | 52        |
| 2.4.1.39 | Universality .....   | 52        |
| 2.4.1.40 | Updateability .....  | 52        |
| 2.4.2    | Organization of Models .....   | 52        |
| 2.4.2.1  | Structure .....  | 53        |
| 2.4.2.2  | Architecture .....   | 57        |
| 2.4.2.3  | Important External Relations .....                                     | 57        |
| 2.5      | Model Representation .....   | 72        |
| 2.5.1    | Reasons for Discussing the Representation .....                        | 72        |
| 2.5.2    | Classification of the Representation Types .....                       | 72        |
| 2.6      | Integration of Models .....  | 73        |
| 2.6.1    | Integration Classification .....                                       | 74        |
| 2.6.2    | Models, (Software) Applications and their Integration .....            | 75        |
| <b>3</b> | <b>Conventional Product and Process Modelling .....</b>                | <b>77</b> |
| 3.1      | Problems of Contemporary Modelling .....                               | 77        |
| 3.1.1    | General Observations .....   | 78        |
| 3.1.1.1  | The Most Popular Modelling Approach .....                              | 78        |
| 3.1.1.2  | Dependency on the Achievements of the Information<br>Technology .....  | 80        |
| 3.1.1.3  | System Centricity of the Conventional (Approach to)<br>Modelling ..... | 81        |
| 3.1.1.4  | Communication .....  | 82        |
| 3.1.1.5  | Security .....   | 83        |
| 3.1.1.6  | Integration-related Issues .....                                       | 83        |
| 3.1.1.7  | Enterprise-related Observations .....                                  | 83        |
| 3.1.1.8  | Lifetime .....   | 85        |
| 3.1.1.9  | Changeability and its Derivatives .....                                | 86        |
| 3.1.1.10 | Mechatronics-specific Requirements/Issues .....                        | 88        |
| 3.1.1.11 | Complexity-related Issues .....  | 88        |
| 3.1.1.12 | Standardization and Standardization-related Issues .....               | 89        |
| 3.1.1.13 | Other Problems .....   | 94        |
| 3.1.2    | Complexity-related Issues .....  | 95        |
| 3.1.2.1  | Towards a Definition .....   | 95        |
| 3.1.2.2  | Observations .....   | 98        |
| 3.1.2.3  | Measuring Complexity .....   | 124       |
| 3.1.2.4  | Improving Dealing with Complexity .....                                | 125       |
| 3.1.2.5  | Complexity of Software Models .....                                    | 128       |
| 3.1.3    | Integration-related Issues .....                                       | 130       |
| 3.1.3.1  | Enterprise View on Integration .....                                   | 130       |
| 3.1.3.2  | Background .....   | 130       |
| 3.1.3.3  | Integration of Two Models: Possible Interpretations .....              | 131       |
| 3.1.3.4  | Integration-related Issues: Conclusion .....                           | 142       |
| 3.2      | Problems Specific to the System Centred Approach .....                 | 144       |

|          |  |            |
|----------|--|------------|
| 3.2.1    | General Observations.....  | 144        |
| 3.2.2    | Problematic Issues .....   | 146        |
| 3.2.2.1  | Usability of a Model .....   | 146        |
| 3.2.2.2  | Reasonability for Use of a Given Tool .....  | 146        |
| 3.2.2.3  | Integration and Communication Problems .....   | 147        |
| 3.3      | Hypothesis .....   | 148        |
| <b>4</b> | <b>Towards Better Product and Process Modelling .....</b>                                | <b>151</b> |
| 4.1      | Understanding the Aims .....   | 151        |
| 4.2      | Requirements for the Perfect Modelling Approach .....                                    | 152        |
| 4.2.1    | First Approximation.....   | 154        |
| 4.2.2    | Demands, Requirements, Parameters .....  | 156        |
| 4.2.3    | Ordering the Requirements .....  | 156        |
| 4.3      | Attempts to Avoid the Drawbacks of Conventional Modelling .....                          | 158        |
| 4.3.1    | Dissatisfaction of Modellers with Existing Solutions .....                               | 158        |
| 4.3.2    | Cooperative Modelling with Transient Objects (Integrated Engineering System).....        | 159        |
| 4.3.3    | Network-centric Virtual Prototyping .....  | 159        |
| 4.3.4    | Component-based CAx-systems .....  | 159        |
| 4.3.5    | Product Data Markup Language (PDML) .....  | 160        |
| 4.3.6    | PDM Enablers, PDM Schemas .....  | 160        |
| 4.3.7    | Innovative Technologies and Systems for Integrated Virtual Product Creation (iViP) ..... | 161        |
| 4.3.8    | Process-centred Development.....   | 161        |
| 4.3.9    | PDGL.....  | 161        |
| 4.3.10   | Model Driven Architecture (MDA).....   | 161        |
| 4.3.11   | Holonic Manufacturing.....   | 162        |
| 4.3.12   | Fractal Manufacturing .....  | 162        |
| 4.3.13   | Others .....   | 163        |
| 4.4      | Modelling Parameters .....   | 163        |
| 4.4.1    | Parameters Enumeration .....   | 163        |
| 4.4.2    | Main Relations Between (Modelling) Parameters and (Functional) Requirements .....        | 164        |
| 4.4.3    | Rank of Influence .....  | 166        |
| 4.5      | Model Centred Approach.....  | 167        |
| 4.5.1    | Idea .....   | 167        |
| 4.5.2    | About the Name.....  | 174        |
| 4.5.3    | Definitions .....  | 174        |
| 4.5.3.1  | Authoring and Authoring Tools.....   | 174        |
| 4.5.3.2  | Host .....   | 175        |
| 4.5.3.3  | Synthesis.....   | 175        |
| 4.6      | Inherencies of MCA.....  | 176        |
| 4.6.1    | A Meta-solution .....  | 176        |
| 4.6.2    | The MCA-commandments .....   | 176        |
| 4.6.3    | Separation of Authoring from Use.....  | 176        |
| 4.6.4    | Separate Modelling .....   | 177        |
| 4.6.5    | Organization and Architecture.....   | 179        |
| 4.6.5.1  | Components.....  | 180        |
| 4.6.5.2  | Hierarchy .....  | 180        |

|          |  |     |
|----------|--|-----|
| 4.6.5.3  | Modelling Hierarchy (Holarchy) .....                                     | 180 |
| 4.6.5.4  | Autonomous Intelligent Entity.....                                       | 182 |
| 4.6.5.5  | Model Independence.....  | 185 |
| 4.6.5.6  | Homogeneity and Distribution .....                                       | 185 |
| 4.6.6    | Integration.....   | 185 |
| 4.6.7    | Achieving High Flexibility .....   | 188 |
| 4.6.7.1  | Model Organization.....  | 188 |
| 4.6.7.2  | Modelling for Reuse .....  | 189 |
| 4.6.7.3  | Extensibility.....   | 191 |
| 4.6.7.4  | Knowledge-based Distributed Decision Taking .....                        | 191 |
| 4.6.8    | Cooperative Work and Distributed Authoring .....                         | 193 |
| 4.6.9    | Lean Modelling.....  | 194 |
| 4.7      | Comparison of MCA and SCA .....  | 195 |
| 4.7.1    | Modelling Efficiency .....   | 197 |
| 4.7.2    | Systems for Modelling (Authoring Tools) vs. (Systems of)<br>Models ..... | 197 |
| <b>5</b> | <b>Conclusion</b> .....  | 199 |
| 5.1      | Based on Highly and Easily Integrable AIEs.....                          | 199 |
| 5.2      | Extremely Flexible and Extendable .....                                  | 200 |
| 5.3      | Network and Web-ready Capabilities .....                                 | 200 |
| 5.4      | Scalability up to and Beyond Distributed Virtual Enterprises .....       | 201 |
| 5.5      | Advantages for Modelling .....   | 201 |
| <b>6</b> | <b>Perspectives</b> .....  | 203 |
| <b>7</b> | <b>Afterword</b> .....   | 207 |
|          | <b>Glossary and Used Abbreviations</b> .....                             | 209 |
|          | <b>Bibliography</b> .....  | 211 |
|          | <b>Index</b> .....   | 219 |

<http://www.springer.com/978-1-84628-908-8>

Modelling in Mechanical Engineering and Mechatronics  
Towards Autonomous Intelligent Software Models

Avgoustinov, N.

2007, XXIV, 226 p. 97 illus., Hardcover

ISBN: 978-1-84628-908-8