

# Contents

|          |                                                    |           |
|----------|----------------------------------------------------|-----------|
| <b>1</b> | <b>Introduction</b>                                | <b>1</b>  |
| 1.1      | Geo-Information Systems                            | 1         |
| 1.1.1    | Historical Development                             | 1         |
| 1.1.2    | Definitions                                        | 2         |
| 1.1.3    | Types of GISs                                      | 3         |
| 1.1.4    | Architecture of GISs                               | 5         |
| 1.2      | Integration of Spatial Information                 | 8         |
| 1.2.1    | Motivation                                         | 8         |
| 1.2.2    | Requirements for a 3D-GIS                          | 8         |
| 1.3      | Goals and Overview                                 | 11        |
| <b>2</b> | <b>Spatial Representations</b>                     | <b>13</b> |
| 2.1      | Representations in 2D Space                        | 13        |
| 2.1.1    | Vector Representation                              | 13        |
| 2.1.2    | Tessellating Representations                       | 15        |
| 2.1.3    | Hybrid Representations                             | 16        |
| 2.1.4    | Analytical Representations                         | 17        |
| 2.2      | Representations in 3D Space                        | 19        |
| 2.2.1    | Vector-based Representation                        | 19        |
| 2.2.2    | Tessellating Representations                       | 20        |
| 2.2.3    | Analytical Representations                         | 23        |
| 2.2.4    | Hybrid Representations                             | 25        |
| 2.3      | Comparison of the Representations                  | 26        |
| 2.4      | Conversions                                        | 29        |
| <b>3</b> | <b>Abstraction from the Spatial Representation</b> | <b>33</b> |
| 3.1      | Approximations                                     | 33        |
| 3.1.1    | The “Bounding-Box World”                           | 33        |
| 3.1.2    | Estimations                                        | 34        |
| 3.2      | The Point-Set Approach                             | 34        |

|          |                                                                               |            |
|----------|-------------------------------------------------------------------------------|------------|
| 3.3      | Topological Abstractions .....                                                | 35         |
| 3.3.1    | The "Blocks World" .....                                                      | 35         |
| 3.3.2    | Cell-Complexes .....                                                          | 36         |
| 3.3.3    | Simplicial Complexes .....                                                    | 37         |
| 3.4      | Valuation .....                                                               | 40         |
| <b>4</b> | <b>A Model for the Integration of Spatial Information</b>                     | <b>41</b>  |
| 4.1      | Classification of Spatial Operations .....                                    | 41         |
| 4.2      | Building Blocks for Spatial Queries .....                                     | 43         |
| 4.2.1    | Basic Building Blocks .....                                                   | 43         |
| 4.2.2    | Advanced Building Blocks .....                                                | 44         |
| 4.3      | A General Notion of Space .....                                               | 46         |
| 4.4      | Extended Simplicial Complexes .....                                           | 51         |
| 4.4.1    | Generation of Convex e-Complexes .....                                        | 56         |
| 4.4.2    | Compressed Representation .....                                               | 63         |
| 4.5      | Transformation of Spatial Representations into e-Complexes .....              | 64         |
| 4.5.1    | Transformations in 2D Space .....                                             | 64         |
| 4.5.2    | Transformations in 3D Space .....                                             | 67         |
| 4.6      | Efficient Geometric Algorithms .....                                          | 69         |
| 4.7      | Foundations of the ECOM-Algebra .....                                         | 79         |
| 4.7.1    | Topological Relationships .....                                               | 81         |
| 4.7.2    | Direction Relationships .....                                                 | 101        |
| 4.7.3    | Topological Operators .....                                                   | 104        |
| 4.7.4    | Metrical Operators .....                                                      | 106        |
| 4.7.5    | Geometric Properties .....                                                    | 108        |
| 4.7.6    | Geometric Cut- and Paste-Operators and Local Operations .....                 | 108        |
| <b>5</b> | <b>Integration of Building Blocks for e-Complexes into a GEO-Model Kernel</b> | <b>111</b> |
| 5.1      | CASE-Building Blocks .....                                                    | 111        |
| 5.1.1    | Integration of Thematic and Spatial Attributes .....                          | 111        |
| 5.1.2    | Object Oriented Modeling Support and Integrity Constraints .....              | 115        |

|          |                                                                                                |            |
|----------|------------------------------------------------------------------------------------------------|------------|
| 5.2      | Service-Building Blocks .....                                                                  | 117        |
| 5.2.1    | Access Methods for GEO-Complexes .....                                                         | 117        |
| 5.2.2    | Spatial Relationship Graphs .....                                                              | 120        |
| 5.3      | Integration of the Building Blocks into the GEO-Model Kernel .....                             | 122        |
| <b>6</b> | <b>Performance Behaviour of Geometric and Topological Algorithms</b> .....                     | <b>125</b> |
| 6.1      | Goals of the Measurements .....                                                                | 125        |
| 6.2      | Data Sources and Mapping of the e-Complexes upon an Extensible<br>Database Kernel System ..... | 125        |
| 6.3      | Spatial Operations and Queries .....                                                           | 127        |
| 6.4      | Results of the Measurements .....                                                              | 129        |
| 6.4.1    | Spatial Operations .....                                                                       | 129        |
| 6.4.2    | Spatial Queries .....                                                                          | 131        |
| 6.4.3    | Comparison with a Boundary Representation .....                                                | 132        |
| <b>7</b> | <b>A Geoscientific Application</b> .....                                                       | <b>135</b> |
| 7.1      | The Examination Area in the Lower Rhine Basin .....                                            | 135        |
| 7.2      | Requirements of Geology for a GIS .....                                                        | 137        |
| 7.2.1    | 3D-Modeling and Visualization of Geologically Defined<br>Geometries .....                      | 137        |
| 7.2.2    | Consistent Management of Geological Objects .....                                              | 139        |
| 7.2.3    | Support of Time and Open GIS .....                                                             | 140        |
| 7.3      | Database Support for a GIS in Geology .....                                                    | 140        |
| 7.3.1    | Object Oriented Modeling of Geologically Defined Geometries ...                                | 140        |
| 7.3.2    | Management of the 3D Geometry and Topology of Geological<br>Objects .....                      | 142        |
| 7.3.3    | 3D-Visualization and Coupling with GIS Tools .....                                             | 145        |
| <b>8</b> | <b>Summary and Outlook</b> .....                                                               | <b>149</b> |
|          | <b>References</b> .....                                                                        | <b>153</b> |
|          | <b>Index</b> .....                                                                             | <b>169</b> |