

# Table of Contents

|   |           |
|---|-----------|
| <b>Symbols and Notation</b> .....                               | <b>v</b>  |
| <b>1 Introduction</b> .....                                     | <b>1</b>  |
| 1.1 Software and its Features .....                             | 1         |
| 1.2 Software Testing .....                                      | 3         |
| 1.3 Testing Interactive Systems .....                           | 4         |
| 1.4 Objectives, and Novelty of the Work .....                   | 5         |
| 1.5 Outline .....   | 6         |
| <b>2 Related Work</b> .....                                     | <b>9</b>  |
| 2.1 Testing Techniques .....                                    | 9         |
| 2.2 Finite-State-Based Test Generation .....                    | 10        |
| 2.3 Digraphs for Modeling and Test Generation .....             | 12        |
| 2.4 Test Generation for GUIs .....                              | 12        |
| 2.5 Conclusion of the Comparison with Related Work .....        | 14        |
| 2.6 Summary .....   | 14        |
| <b>3 Event Sequence Graphs</b> .....                            | <b>15</b> |
| 3.1 Formalization .....   | 15        |
| 3.2 Modeling Functions and Malfunctions .....                   | 20        |
| 3.3 Fault Model .....   | 24        |
| 3.4 Handling Other Features .....                               | 25        |
| 3.5 Summary .....   | 28        |
| <b>4 Test Process, Test Generation and Test Execution</b> ..... | <b>29</b> |
| 4.1 Objectives .....  | 29        |
| 4.2 Test Process .....  | 31        |
| 4.3 Test Generation and Execution Algorithm .....               | 32        |

|          |  |            |
|----------|--|------------|
| 4.4      | Exploiting the Structural Features of SUT for Further Reduction of Test Effort ..... | 41         |
| 4.5      | Test Configuration and Test Cost .....   | 43         |
| 4.6      | Summary.....   | 45         |
| <b>5</b> | <b>Case Study 1: The RealJukebox - RJB.....</b>                                      | <b>47</b>  |
| 5.1      | Objectives.....  | 47         |
| 5.2      | System Description and Model.....  | 48         |
| 5.3      | Test Representation .....  | 51         |
| 5.4      | Test Generation.....   | 52         |
| 5.5      | Results .....  | 54         |
| 5.6      | Analysis of the Results .....  | 59         |
| 5.7      | Fault Detection .....  | 61         |
| 5.8      | Defense Mechanism.....   | 65         |
| 5.9      | Discussion.....  | 66         |
| 5.10     | Summary.....   | 66         |
| <b>6</b> | <b>Considering Safety Aspects .....</b>  | <b>67</b>  |
| 6.1      | Risks and Risk Ordering.....   | 67         |
| 6.2      | Quantification of Robustness.....  | 69         |
| 6.3      | A Comprehensive Example: Railway Crossing.....                                       | 69         |
| 6.4      | Summary.....   | 77         |
| <b>7</b> | <b>Case Study 2: Extending the Approach to Statecharts .....</b>                     | <b>79</b>  |
| 7.1      | Modeling Functions and Malfunctions .....  | 79         |
| 7.2      | Test Criteria and Their Application to Statecharts.....                              | 83         |
| 7.3      | Test Case Generation.....  | 85         |
| 7.4      | Testing the Marginal Strip Mower – RSM13 .....                                       | 86         |
| 7.5      | Discussion: ESG vs. Statecharts .....  | 92         |
| 7.6      | Summary.....   | 94         |
| <b>8</b> | <b>Tool Support.....</b>   | <b>95</b>  |
| 8.1      | Test Case Generation.....  | 95         |
| 8.2      | Test Case Analysis.....  | 97         |
| 8.3      | More Automation – Towards Self-Testing.....  | 99         |
| 8.4      | Remarks for Further Research and Development.....                                    | 108        |
| 8.5      | Summary.....   | 109        |
| <b>9</b> | <b>Discussion and Conclusion.....</b>  | <b>111</b> |
| 9.1      | Advantages and Disadvantages of Modeling with ESG .....                              | 112        |
| 9.2      | Recommendations for Practice .....   | 112        |
| 9.3      | Conclusion and Perspectives for Future Work .....                                    | 114        |
|          | <b>Bibliography .....</b>  | <b>115</b> |
| <b>A</b> | <b>Case Study 1: The RealJukebox - RJB.....</b>                                      | <b>127</b> |
| A.1      | ESGs of the Case Study 1 .....   | 127        |

|          |   |            |
|----------|---|------------|
| A.2      | List of Faults Revealed .....                           | 137        |
| <b>B</b> | <b>Case Study 2: Marginal Strip Mower – RSM13 .....</b> | <b>143</b> |
| B.1      | Statecharts of the Case Study 2.....                    | 143        |
| B.2      | List of Faults Revealed .....                           | 146        |