

# Contents

|          |   |           |
|----------|---|-----------|
| <b>1</b> | <b>Introduction to Artificial Intelligence</b>          | <b>1</b>  |
| 1.1      | Background  | 1         |
| 1.1.1    | Definition  | 1         |
| 1.1.2    | Significance and Growth                                 | 2         |
| 1.2      | History and Evolution of AI                             | 4         |
| 1.2.1    | Symbolic AI (1950s–1980s)                               | 4         |
| 1.2.2    | Connectionist AI (1980s–1990s)                          | 5         |
| 1.2.3    | Modern AI (2000s–Present)                               | 5         |
| 1.3      | AI Paradigms  | 6         |
| 1.3.1    | Expert Systems  | 7         |
| 1.3.2    | Fuzzy Theory Based Systems                              | 8         |
| 1.3.3    | Machine Learning  | 9         |
| 1.3.4    | Deep Learning   | 11        |
| 1.3.5    | Genetic and Evolutionary Systems                        | 12        |
| 1.3.6    | Nature Inspired Systems                                 | 13        |
| 1.3.7    | Foundational Models and Generative AI                   | 15        |
| 1.4      | Traditional Programming Versus AI Programming           | 16        |
| 1.5      | Applications of AI                                      | 18        |
|          | References  | 21        |
| <b>2</b> | <b>Computational Foundation of Generative AI Models</b> | <b>23</b> |
| 2.1      | Background  | 23        |
| 2.2      | Mathematical Foundation                                 | 23        |
| 2.2.1    | Linear Algebra  | 23        |
| 2.2.2    | Probability and Statistics                              | 24        |
| 2.2.3    | Optimization  | 25        |
| 2.2.4    | Information Theory                                      | 25        |
| 2.2.5    | Differential Calculus                                   | 26        |
| 2.2.6    | Markov Chains and Stochastic Processes                  | 27        |
| 2.3      | Core Algorithms and Architectures                       | 28        |
| 2.3.1    | Generative Adversarial Networks (GANs)                  | 28        |

|          |  |           |
|----------|--|-----------|
| 2.3.2    | Variational Autoencoders (VAEs)                                | 29        |
| 2.3.3    | Autoregressive Models  | 30        |
| 2.3.4    | Normalizing Flows  | 30        |
| 2.3.5    | Diffusion Models   | 31        |
| 2.4      | Computational Considerations and Efficiency                    | 32        |
| 2.4.1    | Model Complexity and Resource Requirements                     | 32        |
| 2.4.2    | Memory Efficiency  | 34        |
| 2.4.3    | Inference Speed and Latency                                    | 35        |
| 2.4.4    | Energy Efficiency and Environmental Impact                     | 35        |
| 2.4.5    | Scalability and Distributed Training                           | 36        |
| 2.4.6    | Model Compression and Deployment                               | 37        |
| 2.5      | Workflow Architectures   | 38        |
| 2.5.1    | Fine-Tuning Large Language Models (LLMs)                       | 38        |
| 2.5.2    | Retrieval-Augmented Generation (RAG)                           | 39        |
| 2.5.3    | Prompt Engineering with Pre-trained Models                     | 41        |
| 2.5.4    | Base Foundational Model Using Prompting<br>(Foundation Models) | 42        |
| 2.5.5    | End-to-End Generative Pipelines                                | 43        |
|          | References   | 44        |
| <b>3</b> | <b>Generative AI Techniques and Models</b>                     | <b>45</b> |
| 3.1      | Background   | 45        |
| 3.2      | Literature Review  | 46        |
| 3.3      | GenAI Applications   | 47        |
| 3.3.1    | AI-Generated Art   | 47        |
| 3.3.2    | Healthcare: Drug Discovery and Medical Imaging                 | 50        |
| 3.3.3    | Business: Marketing, Product Design, and Data<br>Augmentation  | 51        |
| 3.3.4    | Synthetic Data Generation: Data Augmentation                   | 52        |
| 3.4      | Foundations of Generative AI                                   | 53        |
| 3.4.1    | Generative Versus Discriminative Models                        | 54        |
| 3.4.2    | Probability Distributions and Sampling                         | 54        |
| 3.4.3    | Latent Spaces  | 54        |
| 3.5      | Generative Models  | 55        |
| 3.5.1    | Variational Autoencoders (VAEs)                                | 55        |
| 3.5.2    | Transformer-Based Models                                       | 56        |
| 3.5.3    | Mathematical Basis and Algorithms                              | 56        |
| 3.5.4    | Probability Theory and Bayesian Inference                      | 56        |
| 3.5.5    | Distributions Optimization Algorithms                          | 57        |
| 3.5.6    | Information Theory   | 57        |
| 3.6      | Techniques of GenAI  | 58        |
| 3.6.1    | Generative Adversarial Networks (GANs)                         | 58        |
| 3.6.2    | Variational Autoencoders (VAE)                                 | 59        |
| 3.7      | Conclusion   | 61        |
|          | References   | 62        |

|          |  |     |
|----------|--|-----|
| <b>4</b> | <b>Foundation Models</b> .....   | 65  |
| 4.1      | Introduction .....   | 65  |
| 4.2      | Background .....   | 66  |
| 4.2.1    | Related Work .....   | 68  |
| 4.2.2    | Applications of Foundation Model .....   | 68  |
| 4.3      | Challenges of Foundation Models .....  | 71  |
| 4.3.1    | Types of Foundation Models .....   | 72  |
| 4.4      | Tasks of Foundation Models .....   | 74  |
| 4.5      | Foundation Models Use-Cases .....  | 75  |
| 4.6      | Future Research Direction .....  | 77  |
|          | References .....   | 78  |
| <b>5</b> | <b>Large Language Models</b> .....   | 81  |
| 5.1      | Background .....   | 81  |
| 5.2      | Evolution of Language Models .....   | 82  |
| 5.2.1    | Statistical Language Models (SLM) .....  | 83  |
| 5.2.2    | Neural Language Models (NLM) .....   | 83  |
| 5.2.3    | Pre-trained Language Models (PLM) .....  | 83  |
| 5.2.4    | Large Language Models (LLM) .....  | 83  |
| 5.3      | Related Work .....   | 84  |
| 5.4      | Large Language Models (LLMs) .....   | 87  |
| 5.4.1    | Key Techniques for LLMs .....  | 88  |
| 5.4.2    | Types of LLMs .....  | 89  |
| 5.4.3    | Tasks of LLMs .....  | 90  |
| 5.4.4    | LLM Frameworks .....   | 92  |
| 5.4.5    | LLMs Applications .....  | 94  |
| 5.4.6    | In Research Community .....  | 95  |
| 5.4.7    | In Specific Domains .....  | 96  |
| 5.5      | Challenges in LLMs .....   | 97  |
| 5.6      | Conclusion .....   | 98  |
|          | References .....   | 98  |
| <b>6</b> | <b>Large Generative Models for Different Data Types</b> .....                    | 103 |
| 6.1      | Background .....   | 103 |
| 6.2      | Text Generative Models in Generative AI: Types, Concepts,<br>and Examples .....  | 103 |
| 6.2.1    | Overview of Text Generative Models .....   | 104 |
| 6.2.2    | Autoregressive Models .....  | 104 |
| 6.2.3    | Seq2Seq Models (Encoder-Decoder Architectures) ....                              | 108 |
| 6.2.4    | Hybrid Models: Combining Retrieval<br>and Generation .....                       | 109 |
| 6.2.5    | Future Directions and Challenges in Text<br>Generative Models .....              | 110 |
| 6.3      | Image Generative Models in Generative AI: Types,<br>Concepts, and Examples ..... | 111 |
| 6.3.1    | Overview of Image Generative Models .....  | 111 |

|       |  |     |
|-------|--|-----|
| 6.3.2 | Generative Adversarial Networks (GANs) .....   | 112 |
| 6.3.3 | Variational Autoencoders (VAEs) .....  | 113 |
| 6.3.4 | Normalizing Flows .....  | 114 |
| 6.3.5 | Diffusion Models .....   | 115 |
| 6.3.6 | Transformer-Based Image Generative Models .....  | 117 |
| 6.3.7 | Hybrid Models: Combining Generative Approaches .....                                     | 118 |
| 6.4   | Speech Generative Models in Generative AI: Types, Concepts, and Examples .....           | 119 |
| 6.4.1 | Overview of Speech Generative Models .....   | 119 |
| 6.4.2 | Autoregressive Speech Generative Models .....  | 119 |
| 6.4.3 | Non-autoregressive Speech Generative Models .....  | 121 |
| 6.4.4 | Latent Variable Models for Speech Generation .....                                       | 123 |
| 6.4.5 | Text-to-Speech (TTS) Models .....  | 124 |
| 6.4.6 | Voice Cloning and Speech Synthesis .....   | 125 |
| 6.4.7 | Challenges and Future Directions in Speech Generation .....                              | 126 |
| 6.5   | Video Generative Models in Generative AI: Types, Concepts, and Examples .....            | 127 |
| 6.5.1 | Overview of Video Generative Models .....  | 127 |
| 6.5.2 | Autoregressive Video Generative Models .....   | 128 |
| 6.5.3 | Generative Adversarial Networks (GANs) for Video Generation .....                        | 129 |
| 6.5.4 | Flow-Based Models for Video Generation .....   | 131 |
| 6.5.5 | Diffusion Models for Video Generation .....  | 132 |
| 6.5.6 | Transformer-Based Models for Video Generation .....                                      | 133 |
| 6.5.7 | Hybrid Models for Video Generation .....   | 134 |
| 6.6   | Audio Generative Models in Generative AI: Types, Concepts, and Examples .....            | 135 |
| 6.6.1 | Overview of Audio Generative Models .....  | 136 |
| 6.6.2 | Autoregressive Audio Generative Models .....   | 136 |
| 6.6.3 | Non-autoregressive Audio Generative Models .....   | 138 |
| 6.6.4 | Latent Variable Models for Audio Generation .....  | 139 |
| 6.6.5 | GAN-Based Audio Generative Models .....  | 141 |
| 6.6.6 | Transformer-Based Audio Generative Models .....  | 142 |
| 6.6.7 | Challenges and Future Directions in Audio Generation .....                               | 143 |
| 6.7   | Programming Code Generative Models in Generative AI: Types, Concepts, and Examples ..... | 144 |
| 6.7.1 | Overview of Programming Code Generative Models .....                                     | 144 |
| 6.7.2 | Autoregressive Programming Code Generative Models .....                                  | 145 |

|          |  |            |
|----------|--|------------|
| 6.7.3    | Challenges and Future Directions in Code Generation .....                          | 151        |
| 6.8      | Multimodal Generative Models in Generative AI: Types, Concepts, and Examples ..... | 152        |
| 6.8.1    | Overview of Multimodal Generative Models .....                                     | 152        |
| 6.8.2    | Text-to-Image Generative Models .....  | 153        |
| 6.8.3    | Multimodal Models for Image and Text Understanding .....                           | 157        |
| 6.8.4    | Audio-Visual Generative Models .....   | 158        |
| 6.8.5    | Multimodal Models for Cross-Modal Retrieval .....                                  | 159        |
| 6.8.6    | Challenges and Future Directions in Multimodal Generative Models .....             | 160        |
|          | References .....   | 161        |
| <b>7</b> | <b>Prompt Engineering</b> .....  | <b>163</b> |
| 7.1      | Background .....   | 163        |
| 7.2      | Foundational Concepts of Prompting .....   | 163        |
| 7.2.1    | What Is a Prompt? .....  | 163        |
| 7.2.2    | Key Principles of Prompting .....  | 164        |
| 7.3      | Prompting Techniques .....   | 166        |
| 7.3.1    | Zero-Shot Prompting .....  | 166        |
| 7.3.2    | One-Shot Prompting .....   | 167        |
| 7.3.3    | Few-Shot Prompting .....   | 168        |
| 7.3.4    | Chain-of-Thought Prompting .....   | 169        |
| 7.3.5    | Instruction Prompting .....  | 170        |
| 7.3.6    | Dynamic Prompting .....  | 171        |
| 7.3.7    | Multi-step Prompting .....   | 172        |
| 7.4      | Prompt Evaluations .....   | 173        |
| 7.4.1    | Introduction to Prompt Evaluations .....   | 173        |
| 7.4.2    | Criteria for Evaluating Prompts .....  | 174        |
| 7.4.3    | Methods for Evaluating Prompts .....   | 175        |
| 7.4.4    | Challenges in Prompt Evaluations .....   | 177        |
| 7.4.5    | Best Practices for Prompt Evaluations .....  | 178        |
| 7.5      | Challenges of Prompting .....  | 179        |
| 7.5.1    | Major Challenges .....   | 179        |
| 7.5.2    | Ways to Improve Prompting Techniques .....   | 183        |
|          | References .....   | 185        |
| <b>8</b> | <b>Applications of Generative AI Models</b> .....                                  | <b>187</b> |
| 8.1      | Background .....   | 187        |
| 8.2      | Applications of Generative AI Models According to Type of Data .....               | 188        |
| 8.2.1    | Text Models .....  | 188        |
| 8.2.2    | Image Models .....   | 192        |
| 8.2.3    | Speech Models .....  | 195        |
| 8.2.4    | Video Models .....   | 196        |

|           |        |  |     |
|-----------|--------|--|-----|
|           | 8.2.5  | Code and Software .....  | 197 |
| 8.3       |        | Applications of Generative AI Models According to Type<br>of Domain .....                              | 197 |
|           | 8.3.1  | Business Intelligence .....  | 198 |
|           | 8.3.2  | Content Creation .....   | 199 |
|           | 8.3.3  | Marketing .....  | 200 |
|           | 8.3.4  | Healthcare .....   | 202 |
|           | 8.3.5  | Others .....   | 203 |
| 8.4       |        | Summary of Generative AI Applications Across Domains<br>and Data Types .....                           | 204 |
|           |        | References .....   | 205 |
| <b>9</b>  |        | <b>Ethics, Governance, Security and Privacy</b> .....  | 209 |
|           | 9.1    | Background .....   | 209 |
|           | 9.2    | Importance of Data Governance, Security, Privacy,<br>and Ethics .....                                  | 210 |
|           | 9.2.1  | Data Governance .....  | 210 |
|           | 9.2.2  | Data Security .....  | 210 |
|           | 9.2.3  | Data Privacy .....   | 211 |
|           | 9.2.4  | Data Ethics .....  | 211 |
|           | 9.3    | Impact of Data Breaches on Individuals and Organizations .....   | 213 |
|           | 9.4    | Role of Data Governance in Protecting Privacy<br>and Ensuring Ethical Use of Data .....                | 216 |
|           | 9.5    | Challenges of Implementing Effective Data Governance<br>Policies .....                                 | 220 |
|           | 9.6    | Ethical Considerations Surrounding the Collection,<br>Storage, and Use of Personal Data in GenAI ..... | 220 |
|           | 9.7    | Legal and Regulatory Frameworks Governing Data Privacy<br>and Ethics in GenAI .....                    | 223 |
|           | 9.8    | Looking to the Future .....  | 225 |
|           |        | References .....   | 225 |
| <b>10</b> |        | <b>Biases and Fairness in LLMs</b> .....   | 229 |
|           | 10.1   | Introduction .....   | 229 |
|           | 10.2   | Background .....   | 230 |
|           | 10.3   | Related Work .....   | 231 |
|           | 10.4   | Biases and Fairness in LLMs .....  | 234 |
|           | 10.4.1 | Biases in LLMs .....   | 234 |
|           | 10.4.2 | Fairness in LLMs .....   | 237 |
|           | 10.5   | Strategies for Mitigating Biases .....   | 239 |
|           | 10.6   | Conclusion .....   | 240 |
|           |        | References .....   | 241 |