Contents

List of Figures, xxi
List of Tables, xxiii
Acknowledgements, xxv
Authors, xxvii

INTRODUCTION, XXIX

SECTION I The Landscape

CHAPTER 1 • What Are Virtual Humans?	3
INTRODUCTION	3
WHAT IS A VIRTUAL HUMAN	3
EXISTING DEFINITIONS OF VIRTUAL HUMAN	5
FROM SELF-DRIVING CAR TO VIRTUAL HUMAN	6
THE TRAITS OF A VIRTUAL HUMAN	6
Physical or Digital?	7
Visual, Auditory or Textual?	7
Embodied or Disembodied?	8
Humanoid or Non-Humanoid?	9
Natural Language or Command-Driven Communication?	9
Autonomous or Controlled?	9
Emotional or Unemotional?	10
Presence of a Personality?	10
Ability to Reason?	11

xi

Can It Learn?	11
Is It Imaginative?	12
Sentient or Non-Sentient?	12
DEMONSTRATING INTELLIGENCE?	12
A VIRTUAL HUMAN PROFILE	13
VIRTUAL HUMANOIDS AND VIRTUAL SAPIENS	14
TOWARDS A WORKING DEFINITION	16
EXAMPLES OF VIRTUAL HUMANS	17
Chatbots	17
Autonomous Agents	18
Conversational Agents	19
Pedagogical Agents	20
Virtual Mentors	20
ARTIFICIAL INTELLIGENCE, MACHINE LEARNING	
AND VIRTUAL HUMANS	21
CONCLUSION	21
REFERENCES MARKETURE ISLAND STATEMENT OF THE PROPERTY OF THE P	And des
CHAPTER 2 • Virtual Humans and Artificial Intelligence	
INTRODUCTION INTRODUCTION	25
AN ARTIFICIAL INTELLIGENCE LANDSCAPE	
Complexity and Sophistication Presentation and Humanness	
Marketing AI versus Real AI THE THREE BIG CHALLENGES IN AI DEVELOPMENT	
THE TURING TEST AND UNCANNY VALLEY	
VIRTUAL HUMANS LANDSCAPE	
ARTIFICIAL INTELLIGENCE VERSUS AUGMENTED	
INITELLICENICE	22
VIRTUAL HUMANS IN SCIENCE FICTION	22
Film and Television	22
Radio	35
	33

Drama	36
Literature	AHW DIVIGUATESTICINU 37
Games	NOTATION 38
CONCLUSION	иопилтта 42
REFERENCES	EA MERKAISAE, EMOTION A
CHAFTER 3 • Body and Senses	49
INTRODUCTION	49
WHAT MAKES AN AVATAR?	49
FACIAL RENDERING	51
FACIAL AND SPEECH ANIMATION	53
HAIR MODELLING	54
Hair Shape Modelling	54
Hair Dynamics	55
Hair Rendering	55
BODY RENDERING/MODELLING	instrumed a dame 55
BODY ANIMATION/MECHANICS	ионъидояти 56
CLOTHES AND CLOTH MODELLING	Би вискразициамоз 57
BODY PHYSIOLOGICAL MODEL	А Г. ВИСИЗА ЭКИСИМЫ 58
SENSES	60 Speech Recognition
Sight	Hilly and General of Marie Control
	U STOAUTSWAY JASUTTAN 62
Other Human Senses	MOITADIMUMMOD CIMA 63
Data as a Sense	63 Machine Learning
Data from a Virtual World	emisyanul/ nolauxis/aso.) 63
Data from a Physical World	64 User and Future Develop
Data from the Cyber-World	64 NATURAL EANGUAGE
CONCLUSION	SUDDILAC JAMSTM 64
REFERENCES	иом

CHAPTER 4 • Mind	7
UNDERSTANDING WHAT CONSTITUTES THE MIND	7
PERCEPTION	72
ATTENTION	73
APPRAISAL, EMOTION AND MOOD	75
PERSONALITY	77
MOTIVATION, GOALS AND PLANNING	79
DECISION-MAKING, PROBLEM-SOLVING AND REASONING	81
World Models	87
MEMORY	84
LEARNING	85
IMAGINATION AND CREATIVITY	87
META-MANAGEMENT AND SELF-MONITORING	89
CONCLUSION	90
REFERENCES	91
Hair Kendering	1/2-1
CHAPTER 5 • Communications	97
INTRODUCTION	97
COMMUNICATIONS: NON-LANGUAGE MODALITIES	97
COMMUNICATIONS: LANGUAGE-BASED MODALITIES	98
Speech Recognition	98
Speech Generation (Text to Speech)	101
NATURAL LANGUAGE UNDERSTANDING	
AND COMMUNICATION	103
Machine Learning	105
Conversation Management	105
Uses and Future Developments	106
NATURAL LANGUAGE GENERATION	107
INTERNAL DIALOGUE	109
CONCLUSION	110
REFERENCES	110

INTRODUCTION BACKGROUND THE SOAR MODEL ACT-R SLOMAN'S H-COGAFF MODEL OPENCOG RODRIGUEZ'S NEUROSCIENCE MODEL LIN'S EMOCOG ARCHITECTURE THE FEARNOT! AFFECTIVE MIND ARCHITECTURE AND PSI MODELS BECKER-ASANO'S WASABI MODEL UNIVERSITY OF SOUTHERN CALIFORNIA'S VIRTUAL HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES CHAPTER 7 Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI 119 120 120 121 125 126 127 128 128 128 128 129 129 120 120 120 121 121 122 125 126 127 127 128 128 128 128 129 129 120 120 120 120 120 120	CHAPTER 6 • Architecture	115
THE SOAR MODEL ACT-R SLOMAN'S H-COGAFF MODEL OPENCOG RODRIGUEZ'S NEUROSCIENCE MODEL LIN'S EMOCOG ARCHITECTURE THE FEARNOT! AFFECTIVE MIND ARCHITECTURE AND PSI MODELS BECKER-ASANO'S WASABI MODEL UNIVERSITY OF SOUTHERN CALIFORNIA'S VIRTUAL HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES CHAPTER 7 Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AL 1190 120 121 126 127 128 128 128 128 128 129 129 129		115
ACT-R SLOMAN'S H-COGAFF MODEL OPENCOG RODRIGUEZ'S NEUROSCIENCE MODEL LIN'S EMOCOG ARCHITECTURE THE FEARNOT! AFFECTIVE MIND ARCHITECTURE AND PSI MODELS BECKER-ASANO'S WASABI MODEL UNIVERSITY OF SOUTHERN CALIFORNIA'S VIRTUAL HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES CHAPTER 7 Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED ALL 120 121 122 125 126 127 128 128 128 128 128 128 128	BACKGROUND	115
SLOMAN'S H-COGAFF MODEL OPENCOG RODRIGUEZ'S NEUROSCIENCE MODEL LIN'S EMOCOG ARCHITECTURE THE FEARNOT! AFFECTIVE MIND ARCHITECTURE AND PSI MODELS BECKER-ASANO'S WASABI MODEL UNIVERSITY OF SOUTHERN CALIFORNIA'S VIRTUAL HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES CHAPTER 7 • Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AL 120 122 122 123 124 125 125 126 127 128 128 128 128 129 129 129 120 120 120 120 120	THE SOAR MODEL	117
OPENCOG RODRIGUEZ'S NEUROSCIENCE MODEL LIN'S EMOCOG ARCHITECTURE THE FEARNOT! AFFECTIVE MIND ARCHITECTURE AND PSI MODELS BECKER-ASANO'S WASABI MODEL UNIVERSITY OF SOUTHERN CALIFORNIA'S VIRTUAL HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES 135 CHAPTER 7 • Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AL INTELLIGENCE ENACTIVE AI CHALLENGES TO EMBODIED AL ISO	ACT-R	119
OPENCOG RODRIGUEZ'S NEUROSCIENCE MODEL LIN'S EMOCOG ARCHITECTURE THE FEARNOT! AFFECTIVE MIND ARCHITECTURE AND PSI MODELS BECKER-ASANO'S WASABI MODEL UNIVERSITY OF SOUTHERN CALIFORNIA'S VIRTUAL HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES CHAPTER 7 • Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AL 150 150 150 150 150 150 150 15	SLOMAN'S H-COGAFF MODEL	120
LIN'S EMOCOG ARCHITECTURE THE FEARNOT! AFFECTIVE MIND ARCHITECTURE AND PSI MODELS BECKER-ASANO'S WASABI MODEL UNIVERSITY OF SOUTHERN CALIFORNIA'S VIRTUAL HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES CHAPTER 7 Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AI 150 150 150 150 150 150 150 15	ODENICOC:	122
LIN'S EMOCOG ARCHITECTURE THE FEARNOT! AFFECTIVE MIND ARCHITECTURE AND PSI MODELS BECKER-ASANO'S WASABI MODEL UNIVERSITY OF SOUTHERN CALIFORNIA'S VIRTUAL HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES CHAPTER 7 Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AI 150 150 150 150 150 150 150 15	RODRIGUEZ'S NEUROSCIENCE MODEL	125
BECKER-ASANO'S WASABI MODEL UNIVERSITY OF SOUTHERN CALIFORNIA'S VIRTUAL HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES CHAPTER 7 Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENCES TO EMBODIED AI 130 131 132 133 134 135 135 135 135 135 135 137 137 137 138 139 139 139 139 139 139 139 139 139 139	LIN'S EMOCOG ARCHITECTURE	126
BECKER-ASANO'S WASABI MODEL UNIVERSITY OF SOUTHERN CALIFORNIA'S VIRTUAL HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES CHAPTER 7 • Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENCES TO EMBODIED AI 130 131 132 133 134 135 135 136 137 138 138 139 140 141 143 144 146 146 147 147 147 147 147		
UNIVERSITY OF SOUTHERN CALIFORNIA'S VIRTUAL HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES 138 CHAPTER 7 • Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AL 150 137 138 139 139 139 139 139 139 139	AND PSI MODELS	128
HUMAN TOOLKIT OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES 138 CHAPTER 7 Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENCES TO EMBODIED AI 150 150 151 152 152 153 155 156 157 157 157 157 157 157	BECKER-ASANO S WASABI MODEL	130
OPENAI INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES 137 REFERENCES 138 CHAPTER 7 • Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENCES TO EMBODIED AI 150 150 150 150 151 155		122
INTEGRATION STANDARDS CRITIQUE AND FUTURES CONCLUSION REFERENCES 138 CHAPTER 7 Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AI 135 135 136 147 148 149 150		181
CRITIQUE AND FUTURES CONCLUSION REFERENCES 138 CHAPTER 7 Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AI 135 137 138 138 143 143 144 145 146 147 147 148 149 CHALLENGES TO EMBODIED AI		185
CONCLUSION REFERENCES 138 CHAPTER 7 Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AI 137 143 144 145 147 147 148 149 149 150		
REFERENCES CHAPTER 7 Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AI 138 143 144 145 146 147 149 150		586
THAPTER 7 ■ Embodiment INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE EMBODIMENT AND COGNITION Intelligence and Emergence Situatedness Embodiment GROUNDING ENACTIVE AI CHALLENGES TO EMBODIED AI 143 144 145 146 147 149 150		
INTRODUCTION FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE INTELLIGENCE INTELLIGENCE Intelligence and Emergence Situatedness Embodiment GROUNDING INTELLIGENCE INTELLIGEN		138
FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE 144 EMBODIMENT AND COGNITION 144 Intelligence and Emergence 146 Situatedness 146 Embodiment 146 GROUNDING 147 ENACTIVE AI 149 CHALLENGES TO EMBODIED AL 150	CHAPTER 7 - Embodiment	143
FROM SYMBOLIC TO EMBODIED ARTIFICIAL INTELLIGENCE 144 EMBODIMENT AND COGNITION 144 Intelligence and Emergence 146 Situatedness 146 Embodiment 146 GROUNDING 147 ENACTIVE AI 149 CHALLENGES TO EMBODIED AL 150	INTRODUCTION	143
INTELLIGENCE 144 EMBODIMENT AND COGNITION 144 Intelligence and Emergence 146 Situatedness 146 Embodiment 146 GROUNDING 147 ENACTIVE AI 149 CHALLENGES TO EMBODIED AL 150	FROM SYMBOLIC TO EMBODIED ARTIFICIAL	
Intelligence and Emergence 146 Situatedness 146 Embodiment 146 GROUNDING 147 ENACTIVE AI 149 CHALLENGES TO EMBODIED AL 150	INTELLIGENCE	144
Situatedness 146 Embodiment 146 GROUNDING 147 ENACTIVE AI 149 CHALLENGES TO EMBODIED AL 150	EMBODIMENT AND COGNITION	144
Embodiment 146 GROUNDING 147 ENACTIVE AI 149 CHALLENGES TO EMBODIED AI 150	Intelligence and Emergence	146
Embodiment 146 GROUNDING 147 ENACTIVE AI 149 CHALLENGES TO EMBODIED AI 150	Situatedness	146
ENACTIVE AI 149 CHALLENGES TO EMBODIED AI 150	Embodiment	146
CHALLENGES TO EMBODIED AL 150	GROUNDING	147
CHALLENGES TO EMBODIED AT 150	ENACTIVE AI	149
	CHALLENGES TO EMBODIED AT	150

VIRTUAL HUMANS AND VIRTUAL WORLDS	151
Assessing Virtual Worlds against Brooks' Five Principles	153
Assessing Virtual Worlds against Other Embodied Models	155
CONCLUSION	155
REFERENCES	156
CHAPTER 8 • Assembling and Assemblages	159
BUILDING A VIRTUAL HUMAN	159
The Natural Language Core	160
Memory and Knowledge	160
Problem-Solving and Decision-Making	100
Representation	100
Emotions and Motivation	100
Embodiment	162
Meta-Management and Personality	163
Its Own Life ROMAGNATE MORAGO	163
HALO – A CASE STUDY	164
THE ROLES OF VIRTUAL HUMANS	166
Intelligent Speaker	167
Customer Service Chatbot	167
Personal Virtual Assistant	168
Virtual Tutor	168
Virtual Non-Player Character	168
Virtual Life Coach	169
Virtual Expert	169
Virtual Persona	170
Virtual Person	171
Digital Immortal	171
And Sentience?	171
Transhuman Space Revisited	171
VIRTUAL HUMANS THROUGH DIFFERENT LENSES	172
The Lens of Trust in Technology	173

The Species Lens	174
The Lens of Personhood	175
MORE THAN THE SUM OF ITS PARTS?	176
REFERENCES	177
Services In the Control of the Contr	
SECTION III Issues and Futures	
CHAPTER 9 • Digital Ethics	181
INTRODUCTION	181
RECENT CONSIDERATIONS OF ETHICS AND VIRTUAL HUMANS	181
Robotics Ethics	181
Machine Morality and Intimacy Ethics	182
Technical and Design Ethics	184
Legal Issues	184
ETHICAL STANDPOINTS AND VIRTUAL HUMANS	185
Utilitarian	186
Deontological	186
Virtue Ethics	186
Situational Ethics	186
Discourse Ethics	186
PRACTICAL IMPLICATIONS	188
ETHICAL GUIDELINES AND RESEARCH	188
Ethical Behaviour	189
Ethical Practice	190
Anonymity	190
Confidentiality	190
Informed Consent	190
Minimal Risk	191
Honesty	191
Privacy	191
Plausibility	192

xviii Contents

Research Governance	19:
Disclosure Disclosure	193
THE 'HUMAN SUBJECT' AND VIRTUAL HUMANS	193
CONCLUSION	195
REFERENCES	195
Ill Issues and Futures	
CHAPTER 10 • Identity and Agency	197
INTRODUCTION	197
RETHINKING IDENTITY	197
Dimension One: Dislocated Avatars	198
Dimension Two: Representative Avatars	198
Dimension Three: Avatars as Toys and Tools	198
Dimension Four: Avatars as Extensions of Self	199
Dimension Five: Avatars as Identity Extensions	199
FORMATIONS AND FORMULATIONS OF IDENTITY	200
Spatial Identities	200
Networked Identities	201
Bridged Identities	201
Discarded or Left-Behind Identities	202
Cyberspace and Virtual Humans	203
UNDERSTANDING AGENCY	
Phenomenological Agency	204
Neurocognitive Agency	205
Attributed Agency	205
AGENCY AND AFFORDANCES	206
PROXEMICS	207
AGENCY AND IDENTITY	209
CONCLUSION	210
REFERENCES	210
191 Transferring a Court Breathast Court Washington	
CHAPTER 11 • Virtual Humans for Education	213
INTRODUCTION	213
LEARNING	213

NETWORKED LEARNING AND TECHNOLOGY-ENHANCED	
LEARNING: SOME DEBATES	215
Networked Learning	215
Technology-Enhanced Learning	216
Online Learning	216
Blended Learning	216
Digital Education	217
VIRTUAL HUMANS AS INTERRUPTION AND CHANGE	19
TO CURRENT PEDAGOGIC PRACTICES	218
USING VIRTUAL HUMANS IN EDUCATIONAL SETTINGS	220
Virtual Humans as Teachable Agents	220
Virtual Humans as Teaching Assistants	220
Virtual Humans for Motivating Learning	223
LEARNING, IMMERSION AND VIRTUAL HUMANS	224
DIRECTIONS FOR FUTURE RESEARCH	224
CONCLUSION	227
REFERENCES SAME A RECORD ROOM OF THE RESIDENCE OF THE RES	227
CHAPTER 12 • Digital Immortality	231
INTRODUCTION	231
BACKGROUND	231
RESEARCH AND LITERATURE	233
MODELS, CONCEPTS AND PRACTICES	233
Models of Grief	234
Digital Grief Concepts	234
Digital Grief Practices	235
FORMS OF DIGITAL IMMORTALITY	236
Digital Immortality Creators	236
Digital Immortality Recipients	236
DIGITAL LEGACY	236
DIGITAL IMMORTALITY AND VIRTUAL HUMANS	237

xx Contents

CREATING DIGITAL IMMORTALITY	239
Passive Updating	241
Interacting with Systems	241
Interacting with People	
Interacting with the Physical World	-
CONSENT AND DIGITAL IMMORTALITY	
CONCLUSION	
REFERENCES WAS A MONTH LONG THE REFERENCES	243
CHAPTER 13 • Futures and Possibilities	
INTRODUCTION	247
FUTURE CAUTION	248
The Gartner Hype-Cycle	248
McLuhan's Tetrad	
FUTURE SCENARIOS	251
Taking Stock: Virtual Humans 2018–2030	251
Developments 2030–2050: Routes to an Artificial Mind	253
Uploading the Brain	253
The Technological Singularity	254
Developments 2050–2100	255
THE THREE CHALLENGES	257
Challenge 1: Improving Humanness	258
Challenge 2: Artificial General Intelligence	258
Challenge 3: 2100 and Onwards – Artificial Sentience and Virtual Sapiens	260
THE ANTHROPOMORPHIC CHALLENGE	260
VIRTUAL SAPIENS: THE FUTURE?	263
REFERENCES REFERENCES	264
Organi Isamorbility Recipients	267
GLOSSARV 271	

INDEX, 279