

Contents

1	Introduction	1
1.1	The Many Faces of AmI	1
1.1.1	The Morphing Power, Constitutive Force, and Disruptive Nature of AmI as ICT Innovations . . .	1
1.1.2	Foundational and Defining Characteristics of AmI . . .	4
1.1.3	The Essence of the (Revisited) AmI Vision	4
1.1.4	AmI as a Novel Approach to Human–Machine Interaction and a World of Machine Learning.	5
1.1.5	Human-Inspired Intelligences in AmI Systems	6
1.1.6	Human-like Cognitive, Emotional, Affective, Behavioral, and Conversational Aspects of AmI	8
1.1.7	Context Awareness and Natural Interaction as Computational Capabilities for Intelligent Behavior	8
1.1.8	Situated Forms of Intelligence as an Emerging Trend in AmI Research and Its Underlying Premises	9
1.1.9	Underpinnings and Open Challenges and Issues	12
1.2	The Scope and Twofold Purpose of the Book.	15
1.3	The Structure of the Book and Its Contents	16
1.4	Research Strategy: Interdisciplinary and Transdisciplinary Approaches	18
	References.	19

Part I Enabling Technologies and Computational Processes and Capabilities

2 Ambient Intelligence: A New Computing Paradigm and a Vision of a Next Wave in ICT 23

2.1 Introduction 23

2.2 The Origin and Context of the AmI Vision 25

2.3 The Current Status, Unrealism, and Technological Determinism of the AmI Vision 27

2.4 AmI Versus UbiComp as Visions 30

2.5 AmI Versus UbiComp as Concepts 32

2.6 UbiComp and AmI: Definitional Issues 33

2.7 More to the Characterizing Aspects of AmI 35

2.8 Typologies for AmI 36

2.9 Paradigmatic, Non-paradigmatic, Pre-paradigmatic, and Post-paradigmatic Dimensions of AmI. 39

2.9.1 ICT and Computing 39

2.9.2 Paradigm and Paradigm Shift 40

2.9.3 Computing Paradigm and AmI as an Instance of a New Computing Paradigm. 41

2.9.4 AmI as a Paradigmatic Shift in Computing 43

2.9.5 Non-paradigmatic Aspects of AmI 45

2.9.6 Pre-paradigmatic and Post-paradigmatic Aspects of AmI 46

2.10 Technological Factors Behind the AmI Vision 47

2.11 Research Topics in AmI 50

2.11.1 Computer Science, Artificial Intelligence, and Networking 50

2.11.2 Middleware Infrastructure 51

2.12 Human-Directed Sciences and Artificial Intelligence in AmI: Disciplines, Fields, Relationships, and Contributions 52

2.12.1 Cognitive Psychology 52

2.12.2 Cognitive Science 53

2.12.3 Artificial Intelligence (AI) 54

2.12.4 Relationship Between Cognitive Psychology, Cognitive Science, and AI 55

2.12.5 Contributions of Cognitive Disciplines and Scientific Areas to AmI. 57

2.12.6 Neuroscience and Cognitive Neuroscience 59

2.12.7 Linguistics: Single and Interdisciplinary Subfields. 60

2.12.8 Human Communication 60

2.12.9 Philosophy 61

2.12.10 Sociology and Anthropology (Social, Cultural,
and Cognitive) 62

References. 63

**3 Context and Context Awareness of Humans and AmI Systems:
Characteristics and Differences and Technological Challenges**

and Limitations 67

3.1 Introduction 67

3.2 Context from a Transdisciplinary Perspective 69

3.3 Context (and Context Awareness) in Human Interaction 71

3.4 Definitional Issues of Context and Their Implications
for Context-Aware Computing 73

3.5 Conceptual Versus Technical Definitions of Context 75

3.6 Definition of Context Awareness 77

3.7 Context Taxonomy 79

3.8 Interactivity Levels of Context-Aware Applications. 81

3.9 Context-Aware Systems. 82

3.9.1 Technological Dimensions and Developments
and Application Domains. 82

3.9.2 There Is Much More to Context than the Physical
Environment 83

3.9.3 Cognitive and Emotional Context-Aware
Applications. 85

3.9.4 Common Examples of Context-Aware
Applications and Services: Mobile Computing 86

3.10 Context Awareness: Challenges and Open Issues 88

3.11 Context and Situation 89

3.12 Individual and Sociocultural Meaning of Context
and Situation 91

3.13 Situated Cognition, Action, and Intelligence. 92

3.14 Context Inference, Ready-Made Behavior,
and Action Negotiation 93

3.15 Situation and Negotiation. 95

3.16 Operationalizing Context: Simplifications, Limitations,
and Challenges 96

3.17 Evaluation of Context-Aware Artifacts. 103

3.17.1 Constructs, Methods, Models, and Instantiations 103

3.17.2 Evaluation Challenges 107

3.18 Design of Context-Aware Applications
and User Participation 109

3.18.1 Major Phase Shifts and Design Methods 109

3.18.2 The Notion of Participation 110

3.18.3 Participatory Design (PD): The Origin
of User Participation 111

- 3.18.4 User-Centered-Design (UCD) 112
- 3.18.5 User-Centrality in AmI 113
- 3.18.6 The Impoverishment of User Participation
and the Loss of Its Political Connotation 114
- 3.18.7 Realities and Contradictions of User Participation
in Context-Aware Computing 116
- 3.19 Empowering Users and Exposing Ambiguities:
Boundaries for Developing Critical User Participatory
Context-Aware Applications 118
- References 123

**4 Context Recognition in AmI Environments: Sensor
and MMES Technology, Recognition Approaches,
and Pattern Recognition Methods 129**

- 4.1 Introduction 129
- 4.2 Sensor Technology 131
 - 4.2.1 Sensor Definition and Sensor Types 131
 - 4.2.2 Sensor Information and Diversity of Sensing
Areas in Context-Aware Systems 131
 - 4.2.3 Emerging Trends in Sensor Technology 132
- 4.3 Miniaturization Trend in AmI 133
 - 4.3.1 Miniature System Devices and Their Potential 133
 - 4.3.2 Early Dust, Skin, and Clay Projects 134
- 4.4 MEMS Technology 136
 - 4.4.1 Defining Characteristics of MMES 136
 - 4.4.2 Large Scale Integrated MEMS 137
 - 4.4.3 Potentials and Advantages 139
 - 4.4.4 Technical and Theoretical Issues and Challenges 141
- 4.5 MEMS and Multi-sensor Fusion and Context-Aware
and Affective Computing 143
- 4.6 Multi-sensor Based Context Awareness 145
 - 4.6.1 Multi-sensor Data Fusion and Its Application
in Context-Aware Systems 145
 - 4.6.2 Layered Architecture for Emotional (and Cognitive)
Context Awareness 146
 - 4.6.3 Visual Approach to (Emotional) Context Reading 149
- 4.7 Research in Emotional and Cognitive Context Awareness 150
- 4.8 Multi-sensor Fusion for Multimodal Recognition
of Emotional States in Affective Computing 151
- 4.9 Multi-sensor Systems: Mimicking the Human Cognitive
Sensation and Perception Processes 153
- 4.10 The State-of-the-Art Context Recognition 158
 - 4.10.1 Context Recognition Process 159
 - 4.10.2 Movement Capture Technologies and Recognition
Approaches 160

- 4.10.3 Context Recognition Techniques, Models, and Algorithms. 167
- 4.10.4 Uncertainty in Context-Aware Computing 180
- 4.10.5 Basic Architecture of Context Information Collection, Fusion, and Processing 185
- References. 189

5 Context Modeling, Representation, and Reasoning:

- An Ontological and Hybrid Approach 197**
- 5.1 Introduction 197
- 5.2 Evolution of Context Modeling and Reasoning. 199
- 5.3 Requirements for Context Representation and Reasoning 201
- 5.4 Representation 201
 - 5.4.1 Unique Identifiers 201
 - 5.4.2 Validation 201
 - 5.4.3 Expressiveness 202
 - 5.4.4 Simplicity, Reuse, and Expandability. 202
 - 5.4.5 Uncertainty and Incomplete Information 202
 - 5.4.6 Generality 203
- 5.5 Reasoning 203
 - 5.5.1 Efficiency, Soundness, and Completeness 203
 - 5.5.2 Multiple Reasoning/Inference Methods 203
 - 5.5.3 Interoperability 203
- 5.6 Requirement for Generic Context Models 204
 - 5.6.1 Heterogeneity and Mobility 204
 - 5.6.2 Relationships and Dependencies 205
 - 5.6.3 Timeliness 205
 - 5.6.4 Imperfection. 205
 - 5.6.5 Reasoning 205
 - 5.6.6 Usability of Modeling Formalisms 206
 - 5.6.7 Efficient Context Provisioning 206
- 5.7 Context Models in Context-Aware Computing:
 - Ontological Approach 207
 - 5.7.1 Origin and Definitional Issues of Ontology 208
 - 5.7.2 Key Characteristics and Fundamentals of Ontology. 210
 - 5.7.3 Ontology Components. 212
 - 5.7.4 Ontological Context Modeling 213
 - 5.7.5 Ontological Context Reasoning. 219
 - 5.7.6 OWL-Based Context Models: Examples of Architectures for Context Awareness. 222
 - 5.7.7 Key Components, Features, and Issues of Architectures of Context-Aware Systems 223
 - 5.7.8 Three-Layer Architecture of Context Abstraction 225

- 5.8 Hybrid Context Models 227
 - 5.8.1 Examples of Projects Applying Hybrid Approach to Representation and/or Reasoning. 228
 - 5.8.2 Towards a Hierarchical Hybrid Model. 231
 - 5.8.3 Limitations of Hybrid Context Models. 232
- 5.9 Modeling Emotional and Cognitive Contexts or States. 234
- 5.10 Examples of Ontology Frameworks: Context-Aware and Affective Computing 236
 - 5.10.1 AmE Framework: A Model for Emotion-Aware AmI 236
 - 5.10.2 Domain Ontology of Context-Aware Emotions. 238
 - 5.10.3 Cognitive Context-Aware System: A Hybrid Approach to Context Modeling 240
- 5.11 Key Benefits of Context Ontologies: Representation and Reasoning 244
- 5.12 Context Ontologies: Open Issues and Limitations 245
- 5.13 Context Models Limitations, Inadequacies, and Challenges . . . 247
 - 5.13.1 Technology-Driven and Oversimplified Context Models 247
 - 5.13.2 Context Models as User Groups Models 250
- 5.14 Holistic Approach to Context Models. 251
- References. 252

6 Implicit and Natural HCI in AmI: Ambient and Multimodal User Interfaces, Intelligent Agents, Intelligent Behavior, and Mental and Physical Invisibility 259

- 6.1 Introduction 259
- 6.2 Definitional Issues, Research Topics, and Shifts in HCI. 260
- 6.3 HCI Design Aspects: Usability, Functionality, Aesthetics, and Context Appropriateness 261
- 6.4 Computer User Interfaces. 263
 - 6.4.1 Key Characteristics 263
 - 6.4.2 Explicit HCI Characterization. 264
 - 6.4.3 Explicit HCI Issues. 264
- 6.5 The New Paradigm of Implicit HCI (iHCI) 266
 - 6.5.1 Internal System Properties of iHCI 266
 - 6.5.2 iHCI Characterization 267
 - 6.5.3 Analyzing iHCI: Basic Issues. 269
- 6.6 Natural Interaction and User Interfaces 270
 - 6.6.1 Application Domains: Context-Aware, Affective, Touchless, and Conversational Systems 270
 - 6.6.2 Naturalistic User Interfaces (NUIs) 272
 - 6.6.3 Multimodality and Multi-channeling in Human Communication 273

- 6.6.4 Multimodal Interaction and Multimodal User Interfaces 273
- 6.6.5 Context Awareness, Multimodality, Naturalness, and Intelligent Communicative Behavior in Human Communication: A Synergic Relationship 274
- 6.7 Intelligence and Intelligent Agents 276
 - 6.7.1 Intelligent Agents in AI and Related Issues 277
 - 6.7.2 Intelligent Agents in AmI and Related Issues: Context-Aware Systems 282
- 6.8 Personalized, Adaptive, Responsive, and Proactive Services in AmI 285
 - 6.8.1 Personalization 285
 - 6.8.2 Adaptation and Responsiveness 288
 - 6.8.3 Anticipation (and Proactiveness) 292
- 6.9 Invisible, Disappearing, or Calm Computing 295
 - 6.9.1 Characterization and Definitional Issues 295
 - 6.9.2 Mental Versus Physical Invisibility and Related Issues 297
 - 6.9.3 Invisibility in Context-Aware Computing 303
 - 6.9.4 Delegation of Control, Reliability, Dependability in AmI: Social Implications 303
 - 6.9.5 Misconceptions and Utopian Assumptions 306
 - 6.9.6 Challenges, Alternative Avenues, and New Possibilities 308
- 6.10 Challenges to Implicit and Natural HCI 311
- 6.11 Interdisciplinary and Transdisciplinary Research 314
- References 314

Part II Human-Inspired AmI Applications

- 7 Towards AmI Systems Capable of Engaging in ‘Intelligent Dialog’ and ‘Mingling Socially with Humans’ 321**
 - 7.1 Introduction 321
 - 7.2 Perspectives and Domains of Communication 323
 - 7.3 Human Communication 323
 - 7.3.1 Nonverbal Communication 325
 - 7.3.2 Verbal Communication: A Theoretical Excursion in Linguistics and Its Subfields 336
 - 7.4 Computational Linguistics and Relevant Areas of Discourse: Structural Linguistics, Linguistic Production, and Linguistic Comprehension 352

- 7.5 Speech Perception and Production: Key Issues and Features. 354
 - 7.5.1 The Multimodal Nature of Speech Perception. 354
 - 7.5.2 Vocal-Gestural Coordination and Correlation
in Speech Communication 358
- 7.6 Context in Human Communication 361
 - 7.6.1 Multilevel Context Surrounding Spoken Language
(Discourse) 362
 - 7.6.2 Context Surrounding Nonverbal Communication
Behavior 364
- 7.7 Modalities and Channels in Human Communication 365
- 7.8 Conversational Systems 366
 - 7.8.1 Key Research Topics. 366
 - 7.8.2 Towards Believable ECAs 367
 - 7.8.3 Embodied Conversational Agents (ECAs) 367
 - 7.8.4 Research Endeavor and Collaboration
for Building ECAs 368
 - 7.8.5 SAIBA (Situation, Agent, Intention, Behavior,
Animation) Framework 369
 - 7.8.6 Communicative Function Versus Behavior
and the Relationship 370
 - 7.8.7 Taxonomy of Communicative Functions
and Related Issues 372
 - 7.8.8 Deducing Communicative Functions
from Multimodal Nonverbal Behavior
Using Context 374
 - 7.8.9 Conversational Systems and Context. 375
 - 7.8.10 Basic Contextual Components in the (Extended)
SAIBA Framework 376
 - 7.8.11 The Role of Context in the Disambiguation
of Communicative Signals 377
 - 7.8.12 Context or Part of the Signal 379
 - 7.8.13 Contextual Elements for Disambiguating
Communicative Signals 380
 - 7.8.14 Modalities and Channels and Their Impact
on the Interpretation of Utterances and Emotions 381
 - 7.8.15 Applications of SAIBA Framework: Text-
and Speech-Driven Facial Gestures Generation 383
 - 7.8.16 Towards Full Facial Animation. 386
 - 7.8.17 Speech-Driven Facial Gestures Based on HUGE
Architecture: an ECA Acting as a Presenter 387
- 7.9 Challenges, Open Issues, and Limitations. 389
- References. 393

- 8 Affective Behavioral Features of AmI: Affective Context-Aware, Emotion-Aware, Context-Aware Affective, and Emotionally Intelligent Systems 403**
- 8.1 Introduction 403
- 8.2 Emotion. 405
 - 8.2.1 Definitional Issues 405
 - 8.2.2 Componential Patterning Approach 406
 - 8.2.3 Motivation and Its Relationship to Emotion 407
 - 8.2.4 Theoretical Models of Emotions: Dimensional, Appraisal, and Categorical Models 409
 - 8.2.5 Emotion Classification. 410
 - 8.2.6 Affect Display 410
 - 8.2.7 A Selection of Relevant Studies 411
- 8.3 Emotional Intelligence: Definitional Issues and Models 412
- 8.4 Affective Computing and AmI Computing 414
 - 8.4.1 Understanding Affective Computing 414
 - 8.4.2 Examples of the State-of-the-Art Application Projects 415
 - 8.4.3 Integration of Affective and AmI Computing: Advancing Emotional Context-Aware Systems 416
 - 8.4.4 More Contributions of Affective Computing to AmI Computing 417
 - 8.4.5 Emotional Intelligence in Affective Computing and Affective AmI 418
 - 8.4.6 Context in Affective Computing: Conversational and Emotional Intelligent Systems. 419
 - 8.4.7 Emotions in AmI Research 420
- 8.5 Affective and Context-Aware Computing and Affective Display 421
 - 8.5.1 Context and Multimodal Recognition 421
 - 8.5.2 Recognizing Affect Display and Other Emotional Cues in Affective and Context-Aware HCI Applications 423
 - 8.5.3 Studies on Emotion Recognition: Classification and Issues 424
- 8.6 Areas of Affective Computing 425
 - 8.6.1 Facial, Prosodic, and Gestural Approaches to Emotion. 425
 - 8.6.2 A Linguistic Approach to Emotion: Emotiveness 426
- 8.7 Facial Expressions and Computing 427
 - 8.7.1 Facial Expressions: Theoretical Perspectives. 428
 - 8.7.2 Recognizing Emotion from Facial Expressions: Humans and HCI Applications 429

- 8.7.3 Research Endeavors in Facial Expression Recognition in HCI. 430
- 8.7.4 The Common Three-Phase Procedure of Facial Expression Recognition 431
- 8.8 Approaches, Frameworks, and Applications 433
 - 8.8.1 Towards Context-Aware Effective AmI Systems: Computing Contextual Appropriateness of Affective States 434
 - 8.8.2 Multimodal Context-Aware Affective Interaction 435
 - 8.8.3 Emotion-Aware AmI. 435
- 8.9 Socially Intelligent AmI Systems: Visual, Aesthetic, Affective, and Cognitive Aspects 436
- 8.10 Evaluation of AmI Systems in Real-World Settings: Emotions and User Experience 440
- 8.11 Issues, Limitations, and Challenges 444
 - 8.11.1 Application of Ability EIF and the Issue of Complexity 444
 - 8.11.2 Debatable Issues of Emotions in Affective Computing and AmI 445
 - 8.11.3 Interpretative and Cultural Aspects of Emotions 447
 - 8.11.4 The Link Between Facial Expressions and Emotions: Controversies and Intricacies. 448
 - 8.11.5 The Significance of the Identification of the Intention of Emotions. 449
 - 8.11.6 The Impact of Multimodality on Emotion Meaning and Interpretation 451
- References. 453

9 The Cognitively Supporting Behavior of AmI Systems: Context Awareness, Explicit Natural (Touchless) Interaction, Affective Factors and Aesthetics, and Presence. 461

- 9.1 Introduction 461
- 9.2 The Usage of the Term ‘Cognition’ in Cognitive Psychology and Cognitive Science 463
- 9.3 Cognitive/Mental Processes 464
- 9.4 Cognitive Context-Aware Computing 465
 - 9.4.1 Internal and External Context. 465
 - 9.4.2 Cognitive Context Awareness. 466
 - 9.4.3 Methods for Capturing Cognitive Context 468
 - 9.4.4 Application Areas of Cognitive Context Awareness. 469
 - 9.4.5 Eye Gaze and Facial Expressions: Cognitive Context That Appears Externally 472
 - 9.4.6 Challenges and Limitations 475

- 9.5 New Forms of Explicit Input and Challenges 477
 - 9.5.1 Speech, Eye Gaze, Facial Expressions,
and Gestures 477
- 9.6 The Relationship Between Aesthetics, Affect,
and Cognition in AmI 481
 - 9.6.1 Affect and Related Concepts and Theories 481
 - 9.6.2 Aesthetics 483
 - 9.6.3 Artifact Experience Versus Aesthetic Experience 485
 - 9.6.4 Appraisal Theory: Emotional Response
to the External Environment 487
 - 9.6.5 Aesthetics and Affect in AmI Design
and Use Context 487
 - 9.6.6 The Evolving Affective-Ambient-Aesthetic
Centric Paradigm 490
 - 9.6.7 Affect and Cognition in the AmI Use Context 491
 - 9.6.8 Relationship Between Affect, Mood,
and Cognition 492
 - 9.6.9 Creativity and the Relationship Between
Affect and Creative Cognition or Thought 494
 - 9.6.10 The Effect of Aesthetics and Intelligent
Behavior of AmI Systems on Mood and Immersion . . . 496
- 9.7 Presence in Computing and AmI 497
 - 9.7.1 Definitions of Presence 497
 - 9.7.2 Expanding and Reconfiguring the Concept
of Presence in AmI 499
 - 9.7.3 Interdisciplinary Research in Presence 500
 - 9.7.4 Challenges to Presence in AmI 502
- References 504

Part III Conclusion

- 10 Concluding Remarks, Practical and Research Implications,
and Reflections 513**
 - 10.1 A Comprehensive Design Approach to AmI Systems 513
 - 10.2 The Need for Interdisciplinary Research 514
 - 10.3 Revisiting the AmI Vision—Rethinking the Notion
of Intelligence—and Fresh Possibilities and Opportunities 515
 - 10.4 The Inconspicuous, Rapid Spreading of AmI Spaces 517
 - 10.5 Future Avenues for AmI Technology Development:
A General Perspective 519
 - 10.6 The Seminal Role of Social Innovation and Participative
and Humanistic Design in the Sustainability
of AmI Technology 521
- References 523



<http://www.springer.com/978-94-6239-129-1>

The Human Face of Ambient Intelligence
Cognitive, Emotional, Affective, Behavioral and
Conversational Aspects

Bibri, S.E.

2015, XXXII, 523 p. 31 illus., 9 illus. in color., Hardcover

ISBN: 978-94-6239-129-1

A product of Atlantis Press