Adaptive Multimodal Interactive Systems
Adaptive Multimodal Interactive Systems
Interactive systems, such as personal navigation devices, cell phones, home entertainment and automotive dashboards systems, are part of our everyday lives. Offering more and more features to their users, these systems however increase in their complexity. In addition, the diversity of the users is constantly growing, for instance with older people using interactive systems. One solution for solving the problem of an increasing user diversity and a growing number of features are systems that adapt themselves to individual users. Such an adaptation comprises different steps and relies on an observation of the user’s behavior and conclusions drawn from these observations. This process is called user modeling. Adaptations are thereafter selected based on the user modeling information. This book introduces a general framework for adapting multimodal interactive system, comprising a detailed discussion of each of the steps required for such an adaptation.

The observation of user behavior is a prerequisite for performing adaptations. Based on an observation of basic events, such as button presses, speech input, or internal state changes, user preferences are derived. Different algorithms extract information from these basic events, such as preferences of the user or a prediction of the most likely following user action. Additional models support the user modeling process. An interaction model describes user actions. We introduce the use of a task model for describing higher-level user-system interactions and for deriving adaptation triggers, such as predicting user actions and detecting user problems.

In this book, adaptations are presented as a set of adaptation patterns, which are similar to patterns known from software or usability engineering. Patterns describe recurring problems and present proven solutions for these problems. Each of these patterns includes a discussion of the context of use. The patterns provide guidance to the system designer for integrating adaptive features into interactive systems. We introduce a novel set of adaptation patterns. These address both graphical interfaces as well as speech-based and multimodal interactive systems. In addition, we describe an adaptation framework that provides tool-support for creating adaptive interactive systems. For
this purpose, the framework introduces an abstraction layer that uses semantic web technology. The adaptations are implemented on top of this abstraction layer by creating an abstract representation of the adaptation patterns, including a system-independent and reusable part and a system-specific part.

In summary, a generic approach for adapting multimodal interactive systems is presented. This approach comprises algorithms for user modeling and a set of adaptation patterns. A reference implementation proves the feasibility of the approach as well as the viability of the user modeling algorithms and adaptation patterns. The evaluation demonstrates that adaptations present a means for improving the usability of interactive systems for an individual user. The conceptual adaptation framework provides a sound foundation for the implementation of adaptations in interactive systems.
Contents

Preface ........................................................................ v

1 Introduction ................................................................. 1
  1.1 Adaptive Multimodal Interactive Systems ................. 3
    1.1.1 Multimodal Interactive Systems ....................... 3
    1.1.2 User Behavior ............................................. 4
    1.1.3 Adaptations ................................................. 5
  1.2 Structure of Adaptive Interactive Systems ................... 5
    1.2.1 General Structure of Adaptive Interactive Systems ... 6
    1.2.2 Models in Adaptive Interactive Systems ............ 8
  1.3 Causes of Adaptation .............................................. 12
  1.4 Outline .................................................................. 13

2 Related Work ............................................................... 15
  2.1 Adaptive Interactive Systems .................................. 16
    2.1.1 Adaptive Hypertext and Adaptive Websites .......... 17
    2.1.2 Adaptive Graphical Interfaces .......................... 19
    2.1.3 Adaptive Speech Interfaces ............................... 23
  2.2 User Modeling for Adaptive Interactive Systems .......... 27
    2.2.1 User Modeling Algorithms ............................... 28
    2.2.2 Plan Recognition and Task Models ..................... 30
    2.2.3 User Modeling Architectures ............................ 31
  2.3 Design Patterns for Adaptations ................................ 32
    2.3.1 Interface and Adaptation Patterns ...................... 33
    2.3.2 Formalization of Design Patterns ....................... 34
  2.4 Semantics in Interactive Systems ............................... 35
    2.4.1 Ontologies in Dialog Systems ........................... 36
    2.4.2 Architectures for Adaptive Interactive Systems ....... 37
  2.5 Discussion ............................................................. 38
3 User Modeling in Interactive Systems .................................. 41
  3.1 User Behavior in Interactive Systems ................................. 42
    3.1.1 User Behavior as a Sequence of Events ......................... 42
    3.1.2 Behavior as Actions and Data ................................ 44
  3.2 Recognizing User Actions in Event Sequences ...................... 45
    3.2.1 Probabilistic Deterministic Finite-state Automata ............. 46
    3.2.2 Describing User Behavior using PDFAs ........................ 48
  3.3 Modeling Tasks in Interactive Systems ............................. 50
    3.3.1 Task Modeling ................................................ 51
    3.3.2 Constructing Task Models .................................... 53
    3.3.3 Task Models in Adaptive Systems ............................... 54
  3.4 Predicting User Actions ........................................... 57
    3.4.1 Predicting One User Action .................................... 58
    3.4.2 Predicting a Sequence of User Actions ......................... 60
    3.4.3 Invoking User Actions ......................................... 64
  3.5 Discussion ....................................................... 64

4 Adaptation Patterns for Interactive Systems .......................... 67
  4.1 General Considerations for Adaptation Patterns ................... 68
    4.1.1 Predictability ................................................ 69
    4.1.2 Transparency ................................................ 70
    4.1.3 Controllability .............................................. 70
    4.1.4 Unobtrusiveness ............................................. 71
    4.1.5 Privacy ..................................................... 71
  4.2 Creating Patterns .................................................. 72
    4.2.1 Identifying Patterns ......................................... 72
    4.2.2 A Pattern Format for Adaptation Patterns for Interactive Systems .............................................. 73
  4.3 An Adaptation Pattern Collection for Interactive Systems ........ 74
    4.3.1 Component Emphasis .......................................... 75
    4.3.2 List Element Selection ....................................... 76
    4.3.3 Alternative Elements ....................................... 76
    4.3.4 Adaptive Help Presentation .................................. 77
    4.3.5 Shortcut Area ............................................... 78
  4.4 Discussion ....................................................... 79

5 AdaGUIDE – An Adaptation Framework .................................... 81
  5.1 Overview of the Architecture .................................... 82
  5.2 A Semantic Representation of Interactive Systems ................. 84
    5.2.1 Ontologies ................................................ 84
    5.2.2 An Ontology for Interactive Adaptive Systems ............... 85
    5.2.3 Instantiating the Models .................................... 88
  5.3 A Framework for Modeling User Behavior ........................... 89
    5.3.1 The User Modeling Component ................................. 90
5.3.2 The User Model .................................. 92
5.3.3 Connecting the User Model and the Ontology .......... 95
5.4 Applying Adaptation Patterns .............................. 96
5.4.1 Representation of Adaptations in the Framework ....... 96
5.4.2 Executing Adaptations ................................ 98
5.5 Implementation ........................................... 99
5.5.1 Reference Implementation ............................... 99
5.5.2 Applying the Framework to a Non-Adaptive Interactive System .................. 102
5.6 Discussion ................................................. 104

6 Evaluation .................................................... 107
6.1 Evaluating Adaptive Interactive Systems .................... 108
6.2 Attitudes of Users towards Adaptive Interactive Systems ... 110
   6.2.1 Users of Adaptive Systems .......................... 110
   6.2.2 Cultural Influence .................................... 110
6.3 Evaluation of the User Modeling Algorithms .................. 112
   6.3.1 Test Data ........................................... 112
   6.3.2 Action Recognition ................................... 113
   6.3.3 Action Prediction .................................... 115
6.4 Evaluation of the Adaptation Approach ....................... 116
   6.4.1 Test Setup ........................................... 117
   6.4.2 Adaptation Pattern: Adaptive Help Presentation .... 119
   6.4.3 Adaptation Pattern: Component Emphasis ............ 122
   6.4.4 Adaptation Pattern: List Element Selection .......... 125
   6.4.5 Adaptation Pattern: Alternative Elements .......... 128
   6.4.6 Adaptation Pattern: Shortcut Area ................ 131
   6.4.7 Evaluation Summary .................................. 135
6.5 Discussion ................................................. 136

7 Summary and Outlook ........................................ 139
7.1 Summary .................................................. 140
7.2 Outlook .................................................. 142

A Adaptation Patterns for Interactive Systems .................. 145
   A.1 Component Emphasis ................................... 145
   A.2 List Element Selection ................................ 146
   A.3 Alternative Elements .................................. 149
   A.4 Adaptive Help Presentation ................................ 150
   A.5 Shortcut Area ........................................... 152

B The Evaluation Questionnaire ................................ 155
List of Figures ................................................................. 161
List of Tables .............................................................. 165
References ................................................................. 167
Index ................................................................................ 183