



Milene Serrano

Reuse-Oriented Approach for Incremental and Systematic Development of Intentional Ubiquitous Applications

Tese de Doutorado

Thesis presented to the Postgraduate Program in Informatics of the Departamento de Informática PUC-Rio, as partial fulfillment of the requirements for the degree of Doutor em Informática.

Advisor: Prof. Carlos José Pereira de Lucena

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Milene Serrano completed her undergraduate studies in Computer Engineering (2001) and received her Masters degree in Computer Science (2003) from the Universidade Federal de São Carlos (UFSCar) – grantee of: CAPES/Master (Scholarship award). She worked at Apyon Studio Project (2005-2006) – grantee of: FAPESP TTI level 4 (Scholarship award) – by developing a model of dependencies to deal with business rules and their financial impact on software maintenance. During her PhD – grantee of: CAPES/PhD (Scholarship award) – at Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio), under the supervision of Professor Carlos José Pereira de Lucena, she had cooperative period at University of Toronto (UofT), under the supervision of Professor John Mylopoulos – grantee of: CNPq/SWE/PhD (Scholarship award). She has experience in Software Engineering and Requirements Engineering by focusing on the paradigms: Multi-Agent Systems, Ubiquitous Computing, Goal-Oriented and Software Reuse.

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To My Beloved Family:
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My Sister *Gabriela*,
My Dear Husband *Maurício*,
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Resumo

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Aplicações ubíquas estão inseridas em ambientes inteligentes integrados ao mundo físico e compostos de usuários com diferentes preferências, dispositivos heterogêneos e vários provedores de serviço e conteúdo. Além disso, essas aplicações são especializadas em oferecer serviços e conteúdos em qualquer lugar e momento, auxiliando os usuários em suas atividades diárias sem incomodá-los. Baseado nesse mundo idealizado, o paradigma “em qualquer lugar e momento” impõe alguns desafios para a comunidade de Engenharia de Software, tais como: heterogeneidade de dispositivos, ambientes distribuídos, mobilidade, satisfação de usuário, adaptação de conteúdo, “sensibilidade” de contexto, privacidade, personalização, transparência, invisibilidade e constante evolução das tendências tecnológicas. Visando lidar com esses novos desafios tecnológicos, é proposta uma abordagem orientada à reutilização de software para desenvolvimento incremental e sistemático de aplicações ubíquas intencionais. Foram escolhidos dois principais objetivos para conduzir a pesquisa dessa tese: (i) a construção de conjuntos de apoio, orientados à reutilização de software, com base em uma investigação detalhada de aplicações ubíquas e do paradigma de Sistemas Multi-Agentes Intencionais – ou seja, *Desenvolvimento para Reutilização*; e (ii) o desenvolvimento incremental e sistemático de aplicações ubíquas, dirigidas por Sistemas Multi-Agentes Intencionais, com base na abordagem orientada à reutilização de software – ou seja, *Desenvolvimento com Reutilização*. Algumas contribuições do nosso trabalho são: (i) uma arquitetura orientada à reutilização de software e baseada nos conjuntos de apoio – i.e. blocos de construção principalmente compostos de modelos conceituais, frameworks, padrões e bibliotecas – obtidos a partir da *Engenharia de Domínio das Aplicações Ubíquas*; (ii) uma *Engenharia de Aplicações Ubíquas* orientada à reutilização de software visando o desenvolvimento incremental e sistemático de aplicações ubíquas com base nos blocos de construção propostos; (iii) um modelo de raciocínio focado em regras condicionais de lógica nebulosa e no modelo “Crença-Desejo-Intenção”

para melhorar a capacidade cognitiva dos agentes; (iv) um mecanismo específico, baseado em agentes intencionais, para lidar com questões de privacidade, balanceando privacidade e personalização bem como transparência e invisibilidade; (v) um catálogo que graficamente apresenta os principais requisitos não-funcionais ubíquos, as interdependências entre eles e formas de se operacionalizá-los com base na combinação de tecnologias tradicionais e emergentes; (vi) ontologias para permitir a construção dinâmica de interfaces e melhorar a comunicação e inter-operabilidade dos agentes de software; e (vii) um modelo de banco de dados dinâmico para carregar e recuperar os perfis ubíquos (ex. perfis de usuário, dispositivo, rede e contrato), melhorando o gerenciamento de dados em tempo de execução. A abordagem proposta foi avaliada desenvolvendo diferentes aplicações ubíquas (ex. aplicações ubíquas de comércio eletrônico e de clínica odontológica).

Palavras-chave

Engenharia de Software, Desenvolvimento Incremental e Sistemático, Intencionalidade, Computação Ubíqua, Sistemas Multi-Agentes, Engenharia de Domínio das Aplicações Ubíquas, Engenharia de Aplicações Ubíquas, Reusabilidade de Software

Abstract

Serrano, Milene; Lucena, Carlos José Pereira de. **Reuse-Oriented Approach for Incremental and Systematic Development of Intentional Ubiquitous Applications**. Rio de Janeiro, 2011. 228p. Doctoral Thesis - Departamento de Informática, Pontifícia Universidade Católica do Rio de Janeiro.

Ubiquitous applications are embedded in intelligent environments integrated into the physical world and composed of users with different preferences, heterogeneous devices and several content and service providers. Moreover, they focus on offering services and contents anywhere and at any time by assisting the users in their daily activities without disturbing them. Based on this idealized world, the “anywhere and at any time” paradigm poses some challenges for the Software Engineering community, such as: device heterogeneity, distributed environments, mobility, user satisfaction, content adaptability, context awareness, privacy, personalization, transparency, invisibility and constant evolution of technological trends. In order to deal with these new technological challenges, we propose a *Reuse-Oriented Approach for Incremental and Systematic Development of Intentional Ubiquitous Applications*. We have chosen two main goals that drive our research in this thesis: (i) the construction of reuse-oriented support sets based on an extensive investigation of ubiquitous applications and the Intentional-Multi-Agent Systems paradigm – i.e. *Development for Reuse*; and (ii) the incremental and systematic development of Intentional-Multi-Agent-Systems-driven ubiquitous applications based on the reuse-oriented approach – i.e. *Development with Reuse*. Some contributions of our work are: (i) a reuse-oriented architecture centered on support sets – i.e. building blocks mainly composed of conceptual models, frameworks, patterns and libraries – obtained from the *Domain Engineering of Ubiquitous Applications*; (ii) a reuse-oriented *Ubiquitous Application Engineering* for incremental and systematic development of intentional ubiquitous applications centered on the proposed building blocks; (iii) a reasoning engine focused on fuzzy conditional rules and the Belief-Desire-Intention model to improve the agents’ cognitive capacity; (iv) a specific mechanism based on intentional agents to deal with privacy issues by balancing privacy and personalization as well as transparency and invisibility; (v) a catalogue that graphically presents the main ubiquitous non-functional

requirements, their interdependencies and ways to operationalize them based on the combination of traditional and emergent technologies; (vi) ontologies to allow the dynamic construction of interfaces and to improve the communication and inter-operability of software agents; and (vii) a dynamic database model to store and retrieve the ubiquitous profiles (e.g. user, device, network and contract profiles) by improving the data management “on the fly”. The proposed approach was evaluated by developing different ubiquitous applications (e.g. e-commerce and dental clinic ubiquitous applications).

Keywords

Software Engineering, Incremental Systematic Development, Intentionality, Ubiquitous Computing, Multi-Agent Systems, Domain Engineering of Ubiquitous Applications, Ubiquitous Application Engineering, Software Reuse

Summary

1. Introduction	23
1.1. Research Questions	24
1.2. Contributions	28
1.3. Thesis Outline	31
2 . State-Of-The-Art	34
2.1. Ubiquitous Computing	34
2.2. Multi-Agent Systems (MAS)	42
2.3. Goal-Orientation	49
2.4. Software Reuse	50
2.5. The Paradigms' Combination	52
2.6. Closing Remarks	54
3 . Related Work: Traditional & Emergent Approaches	55
3.1. RUP	55
3.2. TROPOS	56
3.3. GAIA	57
3.4. Agile Methods	58
3.5. Mobile-D	59
3.6. Our Reuse-Oriented Approach vis-à-vis Related Work	60
3.7. Closing Remarks	60
4 . Domain Engineering of Ubiquitous Applications	62
4.1. Intentional Modeling Building Block	64
4.2. NFR Catalogue Building Block	68
4.3. Integration Building Block	76
4.4. Intentional Agents' Reasoning Building Block	78
4.5. Dynamic Interface Construction Building Block	81
4.6. Ubiquity Issues Building Bocks	90
4.7. Dynamic Database Building Block	95

4.7.1. Type-Square Architecture	95
4.7.2. WURFL Repository & Persistence Framework	99
4.8. Closing Remarks	101
 5 . Reuse-Oriented Approach for Incremental and Systematic Development of Intentional Ubiquitous Applications	 103
5.1. Working with Reuse-Oriented Building Blocks	105
5.1.1. Intentional Modeling Building Block Reuse	105
5.1.2. NFR Catalogue Building Block Reuse	106
5.1.3. Integration Building Block Reuse	107
5.1.4. Intentional Agents' Reasoning Building Block Reuse	109
5.1.5. Fuzzy-Logic-Based Package Reuse	110
5.1.6. Dynamic Interface Construction Building Block Reuse	112
5.1.7. Ubiquity Issues Building Blocks Reuse	114
5.1.8. Dynamic Database Building Block Reuse	116
5.2. Reuse-Oriented Architecture	117
5.3. Incremental and Systematic Development Life-Cycle	119
5.4. Closing Remarks	128
 6 . Our Proposal's Application	 129
6.1. Dental Clinic Ubiquitous Application Engineering	130
6.1.1. Early Requirements & Late Requirements	132
6.1.2. Architectural Design & Detailed Design	146
6.1.3. Implementation	152
6.1.4. Test	178
6.2. Closing Remarks	185
 7 . Our Proposal's Evaluation	 186
7.1. Overview of the Developed Case Studies	186
7.2. Competences Determination for the Dental Clinic Case Study	189
7.3. Simulated Environment for the Dental Clinic Case Study	190
7.4. Participants for the Evaluation of the Dental Clinic Case Study	191
7.5. Analysis of the Results for the Dental Clinic Case Study	193
7.6. Dedication Time and Team Effort for each Discipline of the Life-Cycle	198

7.7. Third Party Point of View	203
7.8. Closing Remarks	205
8 . Final Considerations	207
8.1. Main Contributions	208
8.2. Limitations	213
8.3. Future Work	214
A. List of Publications (PhD related)	225
A.1 Chapters in Books	225
A.2 Contributions at International Conferences	225
A.3 Contributions at Brazilian Symposiums, Conferences and Workshops	226
B. List of Technical Reports (PhD related)	227
B.1 Monographs (selected)	227

List of Figures

Figure 2.1 - Ubiquitous scenarios	35
Figure 2.2 - Smart-Spaces	37
Figure 2.3 - Ubiquitous Computing definition	39
Figure 2.4 - Multi-Agent System	43
Figure 2.5 - Mobile agents	44
Figure 2.6 - Agent's life-cycle	44
Figure 2.7 - Mobile agents in ubiquitous contexts	45
Figure 2.8 - Intelligent dental clinic	47
Figure 2.9 - E-commerce-based scenario	48
Figure 2.10 - Search for information by using mobile agents	48
Figure 2.11 - Situation in which the user is moving	52
Figure 2.12 - Situation in which the environment is modified	53
Figure 2.13 - Situation in which the context is modified	54
 Figure 3.1 - Our approach vis-à-vis traditional and emergent approaches	 61
 Figure 4.1 - Reusable <i>Building Blocks</i> for intentional ubiquitous applications	 62
Figure 4.2 - Example of i* model based on the dental clinic domain	65
Figure 4.3 - <i>Intentional Modeling Building Block</i> packages	66
Figure 4.4 - Association between abstractions of intentional-MAS-driven ubiquitous applications and i* abstractions	67
Figure 4.5 - Find-a-Friend ubiquitous design pattern	67
Figure 4.6 - Example of NFR SIG notation	69
Figure 4.7 - <i>NFR Catalogue Building Block</i> packages	69
Figure 4.8 - Meta-model of the used activity-based representation	72
Figure 4.9 - <i>NFR Catalogue Usage Method – Explore</i> activity	73
Figure 4.10 - <i>NFR Catalogue Usage Method – Collect</i> activity	73
Figure 4.11 - <i>NFR Catalogue Usage Method – Model</i> activity	74

Figure 4.12 - <i>NFR Catalogue Usage Method – Operationalize</i> activity	75
Figure 4.13 - <i>NFR Catalogue Usage Method – Validate</i> activity	75
Figure 4.14 - <i>Integration Building Block</i> packages	77
Figure 4.15 - <i>Intentional Agents' Reasoning Building Block</i> packages	80
Figure 4.16 - <i>Fuzzy-Logic-Based Support</i> complementary package	81
Figure 4.17 - Ontological Java class	83
Figure 4.18 - Ontology vocabulary for <i>Interface Elements</i>	84
Figure 4.19 - Registering content language and ontology using a behavioral <i>Interface Agent</i>	85
Figure 4.20 - Registering content language and ontology using an <i>Intentional Agent</i>	85
Figure 4.21 - Creating/manipulating the content expressions of <i>MIDP GUI Ontology</i> as Java objects using the <i>Interface Agent</i>	86
Figure 4.22 - Manipulating the content expressions of <i>MIDP GUI Ontology</i> using the <i>Intentional Agent (DecideRPRequestPlan)</i>	86
Figure 4.23 - Manipulating the content expressions of <i>MIDP GUI Ontology</i> using the <i>Intentional Agent (ExecuteRPRequestPlan)</i>	87
Figure 4.24 - <i>Dynamic Interface Construction Building Block</i> packages	89
Figure 4.25 - <i>Ubiquity Issues Building Block</i> packages	90
Figure 4.26 - The proposed content adaptability process	92
Figure 4.27 – <i>Type-Square</i> architecture	96
Figure 4.28 - Dynamic database architecture (first example)	97
Figure 4.29 - Dynamic database architecture (second example)	99
Figure 4.30 - Code fragment of the WURFL XML file	100
Figure 4.31 – <i>Dynamic Database Building Block</i> packages	101
Figure 5.1 - Development of intentional-MAS-driven ubiquitous applications based on a reuse-based approach	104
Figure 5.2 - Reuse of the <i>Intentional Modeling Building Block</i> in the <i>Ubiquitous Application Engineering</i>	106
Figure 5.3 - Reuse of the <i>NFR Catalogue Building Block</i> in the <i>Ubiquitous Application Engineering</i>	107
Figure 5.4 - Reuse of the <i>Integration Building Block</i> in the <i>Ubiquitous Application Engineering</i>	108

Figure 5.5 - Reuse of the <i>Intentional Agents' Reasoning Building Block</i> in the <i>Ubiquitous Application Engineering</i>	110
Figure 5.6 - Reuse of the <i>Fuzzy-Logic-Based</i> package in the <i>Ubiquitous Application Engineering</i>	111
Figure 5.7 - Reuse of the <i>Dynamic Interface Construction Building Block</i> in the <i>Ubiquitous Application Engineering</i>	113
Figure 5.8 - Reuse of the <i>Ubiquity Issues Building Block</i> in the <i>Ubiquitous Application Engineering</i>	114
Figure 5.9 - Agents' adaptation strategies	115
Figure 5.10 - Reuse of the <i>Dynamic Database Building Block</i> in the <i>Ubiquitous Application Engineering</i>	116
Figure 5.11 - <i>Ubiquitous Profiles</i> and the <i>Dynamic Data Model</i>	117
Figure 5.12 - The proposed <i>Reuse-Oriented Architecture</i>	118
Figure 5.13 - Life-cycle: <i>Incremental and Systematic Development</i>	120
Figure 5.14 - <i>Early Requirements</i> discipline	121
Figure 5.15 - <i>Late Requirements</i> discipline	122
Figure 5.16 - <i>Architectural Design</i> discipline	123
Figure 5.17 - <i>Detailed Design</i> discipline	124
Figure 5.18 - <i>Implementation</i> discipline	125
Figure 5.19 - Association between <i>i*</i> abstractions and <i>JADEX BDI Model</i> abstractions	126
Figure 5.20 - <i>Test</i> discipline	127
Figure 6.1 - Architecture for the <i>Dental Clinic Ubiquitous Application Engineering</i>	131
Figure 6.2 - Some early elicitation information acquired by using different elicitation techniques	133
Figure 6.3 - <i>Early Requirements i*</i> SD model for patient's registration process	134
Figure 6.4 - Detailed dental clinic scenario for patient's registration process	136
Figure 6.5 - <i>Late Requirements i*</i> SD model – Patient / Application / Attendant – for patient's registration process	137
Figure 6.6 - Some late elicitation information acquired by using different elicitation techniques	138

Figure 6.7 - <i>NFR Catalogue Usage Method</i> instantiated from the <i>Dental Clinic Ubiquitous Application Engineering – Explore</i> activity	139
Figure 6.8 - <i>Software Mobility</i> SIG from our <i>NFR Catalogue</i>	140
Figure 6.9 - <i>Late Requirements</i> i* SD model – Patient / Ubiquitous Application / Attendant – for patient’s registration process centered on patient privacy and device heterogeneity issues	141
Figure 6.10 - <i>NFR Catalogue Usage Method</i> instantiated from the <i>Dental Clinic Ubiquitous Application Engineering – Collect</i> activity	142
Figure 6.11 - <i>NFR Catalogue Usage Method</i> instantiated from the <i>Dental Clinic Ubiquitous Application Engineering – Model</i> activity	142
Figure 6.12 - <i>NFR Catalogue Usage Method</i> instantiated from the <i>Dental Clinic Ubiquitous Application Engineering – Operationalize</i> activity	143
Figure 6.13 - Evolved part of the <i>Software Mobility</i> SIG	143
Figure 6.14 - <i>NFR Catalogue Building Block</i> in the <i>Dental Clinic Ubiquitous Application Engineering</i>	144
Figure 6.15 - More complete i* SD model centered on privacy, invisibility and mobility issues	145
Figure 6.16 - More complete i* SD model centered on privacy, invisibility, mobility and adaptability issues	147
Figure 6.17 - i* SR model for the intentional <i>Mobile Agent – Mobility Capability</i>	149
Figure 6.18 – <i>Privacy [Patient]</i> decomposition	150
Figure 6.19 - i* SR model for the intentional <i>Personal Agent</i>	151
Figure 6.20 - Reuse of the <i>Autonomous Entity Support</i> in the <i>Dental Clinic Ubiquitous Application Engineering</i>	154
Figure 6.21 - <i>Agent Definition File</i> for the <i>Mobile Agent</i> of the dental clinic ubiquitous application	154
Figure 6.22 - <i>Mobile Agent’s plan – MoveAgentPlan.java</i> – to perform the migration from one server to another in the dental clinic ubiquitous application	155
Figure 6.23 - BDI-model-based engine for dental clinic’s intentional software agents	156
Figure 6.24 - Code fragment for the patient’s registration in the dental clinic ubiquitous application	156

Figure 6.25 - Reuse of the <i>Ubiquitous Application-Based Capability</i> in the <i>Dental Clinic Ubiquitous Application Engineering</i>	157
Figure 6.26 - <i>KnowTheContextPlan.java</i> based on the <i>Privacy-Aware Capability</i> model	159
Figure 6.27 - <i>ExecuteRPRequestPlan.java</i> based on the <i>Privacy-Aware Capability</i> model	159
Figure 6.28 - Reuse of the <i>Fuzzy Logic-Based Support</i> in the <i>Dental Clinic Ubiquitous Application Engineering</i>	160
Figure 6.29 - The fuzzy logic sets for fuzzy variables	161
Figure 6.30 - XML code fragment with beliefs, goals and intentions specified to find a dental clinic service centered on the fuzzy rules base	164
Figure 6.31 - Code fragment based on the fuzzy rule base's creation	165
Figure 6.32 - Code fragment based on the service analysis	165
Figure 6.33 - Code fragment based on the best service determination	166
Figure 6.34 - The asserted model for the ontology of the dental clinic forms	167
Figure 6.35 - The XML code of the dental clinic forms ontology	167
Figure 6.36 - Instances of the developed dental forms ontology for the <i>Anamneses Form</i>	168
Figure 6.37 - Dental Clinic Forms Ontological Java class	169
Figure 6.38 - Dental Clinic Forms Ontology vocabulary for <i>Interface Elements</i>	169
Figure 6.39 - Registering SL content language and <i>MIDP GUI Ontology</i> using the behavioral <i>Interface Agent</i> in the dental clinic ubiquitous application	170
Figure 6.40 - Registering SL content language and <i>Dental Forms Ontology</i> using the intentional <i>Personal Agent</i> in the dental clinic ubiquitous application	170
Figure 6.41 - Creating/manipulating the content expressions of the <i>MIDP GUI Ontology</i> as Java objects using the <i>Interface Agent</i> in the dental clinic ubiquitous application	170
Figure 6.42 - Manipulating the content expressions of the <i>Dental Forms Ontology</i> using the <i>Personal Agent (DecideRPRequestPlan)</i> in the dental clinic ubiquitous application	171
Figure 6.43 - Manipulating the content expressions of the <i>Dental Forms</i>	

Ontology using the <i>Personal Agent (ExecuteRPRequestPlan)</i> in the dental clinic ubiquitous application	171
Figure 6.44 - <i>Adaptation Service</i> by associating the <i>Dental Clinic Forms Ontology</i> and the <i>GUI Generic Ontology</i> in the <i>Dental Clinic Ubiquitous Application Engineering</i>	172
Figure 6.45 - Code fragment of the <i>AbstractDecideServiceRequestPlan.java</i> of the <i>IFCAUC</i>	173
Figure 6.46 - Code fragment of the <i>AbstractExecuteServiceRequestPlan.java</i> of the <i>IFCAUC</i>	174
Figure 6.47 - Content adaptation process in the dental clinic ubiquitous application	174
Figure 6.48 - Reuse of the <i>Ubiquity Issues Building Block</i> in the <i>Dental Clinic Ubiquitous Application Engineering</i>	175
Figure 6.49 - Reuse of the <i>Dynamic Database Building Block</i> in the <i>Dental Clinic Ubiquitous Application Engineering</i>	176
Figure 6.50 - Instances of the <i>User Profile</i> and <i>Device Profile</i> in the dental clinic ubiquitous case study	177
Figure 6.51 - Agents' way-of-working during the patient's registration process	179
Figure 6.52 - Adapted <i>Registration Form</i> for a MIDP device	182
Figure 6.53 - Privacy-centered investigation from a MIDP device	183
Figure 6.54 - Adapted <i>Anamneses Dental Form</i> for a MIDP device	184
Figure 6.55 - Adapted x-rays for heterogeneous devices and the <i>JADEX Control Center</i> support	184
Figure 7.1 - Some projects developed from 2007 to 2011	187
Figure 7.2 - Simulated environment to perform the evaluation process	191
Figure 7.3 - Results based on the participants' knowledge on using electronic devices and their accordance on using them to perform the dental clinic's activities	192
Figure 7.4 - Frequency Distribution based on the evaluations of the <i>Behavioral-Agent-Based Adaptability</i> and the <i>Intentional-Agent-Based Adaptability</i> competences	194
Figure 7.5 - Frequency distribution based on the evaluation of the	

<i>Invisibility</i> competence	195
Figure 7.6 - Frequency distribution based on the evaluation of the <i>Usability</i> competence	196
Figure 7.7 - Frequency distribution based on the evaluation of the <i>Dependability</i> competence	196
Figure 7.8 - Frequency distribution based on the evaluation of the <i>Response Time</i> competence	197
Figure 7.9 - Frequency distribution based on the evaluation of the <i>Mobility</i> competence	198
Figure 7.10 - Dedication time and team effort for <i>Early Requirements</i> discipline	199
Figure 7.11 - Dedication time and team effort for <i>Late Requirements</i> discipline	200
Figure 7.12 - Dedication time and team effort for <i>Architectural Design</i> discipline	201
Figure 7.13 - Dedication time and team effort for <i>Detailed Design</i> discipline	202
Figure 7.14 - Dedication time and team effort for <i>Implementation</i> discipline	202
Figure 7.15 - Dedication time and team effort for <i>Test</i> discipline	203
Figure 7.16 - Intentional agents' model for crowd simulation	204
Figure 8.1 - Product line view for our reuse-oriented approach	212

List of Tables

Table 4.1 - Summary of the main ubiquitous NFRs issues addressed by our models	71
Table 4.2 - GUI Elements & MIDP GUI Elements	88
Table 6.1 - Main activities of the dental clinic cognitive domain focused on Patient and Attendant stakeholders	134
Table 6.2 - Main stakeholders of the dental clinic case study	136
Table 6.3 - The fuzzy logic base for the dental clinic case study	161
Table 6.4 - The fuzzy conditional rules for the price and the security variables	162
Table 6.5 - The fuzzy conditional rules for the variables price AND security (abusive fuzzy set)	163
Table 6.6 - Dental Forms Elements & GUI Elements	168
Table 7.1 - Description of the analyzed competences	190
Table 7.2 - Questionnaire of the participants	192

List of Abbreviations

AD (Models) or AD (Discipline) - **A**rchitectural **D**esign (Models) or
Architectural **D**esign (Discipline)

ADF - **A**gent **D**efinition **F**ile

AMS - **A**gent **M**anagement **S**ystem (i.e. White Pages)

BDI - **B**elief **D**esire **I**ntention

C&L - **C**enários e **L**éxico (in english: Scenarios and Lexicon)

CC/PP - **C**omposite **C**apability/**P**reference **P**rofiles

DAO - Data Access Object

DD (Models) or DD (Discipline) - **D**etailed **D**esign (Models) or **D**etailed
Design (Discipline)

DF - **D**irectory **F**acilitator (i.e. Yellow Pages)

DQDB - **D**istributed **Q**ueue **D**ual **B**us

ER (Models) or ER (Discipline) - **E**arly **R**equirements (Models) or **E**arly
Requirements (Discipline)

FIPA - **F**oundation for **I**ntelligent **P**hysical **A**gents

GAIA - **G**eographically-**A**ware **I**ntelligent **A**gents

GORE - **G**oal-**O**riented **R**equirements **E**ngineering

GPRS - **G**eneral **P**acket **R**adio **S**ervice

GUI - **G**raphical **U**ser **I**nterface

HQL - Hibernate Query Language

I (Discipline) - **I**mplementation (Discipline)

i* - iStar or Distributed Intentionality

IDE - **I**ntegrated **D**evelopment **E**nvironment

IFCAUC - **I**ntentional **F**ramework for **C**ontent **A**daptation in **U**biquitous
Computing **S**ystems

JADE-LEAP - **J**ava **A**gent **D**evelopment **E**nvironment-**L**ightweight
Extensible **A**gent **P**latform

JADEX - **J**ava **A**gent **D**evelopment **E**nvironment **eX**tension

JCC - **J**adex **C**ontrol **C**enter

JCP - **J**ava **C**ommunity **P**rocess

Jme or Java ME - **J**ava **m**icro **e**diti**o**n

Jse or Java SE - **J**ava **s**tandard **e**diti**o**n

LR (Models) or LR (Discipline) - **L**ate **R**equirements (Models) or **L**ate
Requirements (Discipline)

MAS - **M**ulti-**A**gent **S**ystem

MIDP - **M**obile **I**nformation **D**evice **P**rofile

MVC - **M**odel **V**iew **C**ontroller

NFR - **N**on-**F**unctional **R**equirements

OME - **O**rganization **M**odelling **E**nvironment

PDA - **P**ersonal **D**evice **A**ssistant

PJAVA - **P**ersonal **J**AVA

RUP - **R**ational **U**nified **P**rocess

SADT - **S**tructured **A**nalysis and **D**esign **T**echnique

SD - **S**trategic-**D**ependency

SIG - **S**oftgoals **I**nterdependency **G**raphs

SMDS - **S**witched **M**ultimegabit **D**ata **S**ervices

SOA - **S**ervice-**O**riented **A**rchitecture

SONET - **S**ynchronous **O**ptical **N**ETwork

SOUPA - **S**tandard **O**ntology for **U**biquitous and **P**ervasive **A**pplications

SR - **S**trategic-**R**ationale

T (Discipline) - **T**est (Discipline)

TROPOS - from ***trepō*** in Greek, which means "turning or adopting a new
manner"

UML - **U**nified **M**odeling **L**anguage

UMTS - **U**niversal **M**óbile **T**elecommunication **S**ystem

URL - **U**niform **R**esource **L**ocation

WAP - **W**ireless **A**pplication **P**rotocol

Windows CE - **W**indows **E**mbedded **C**ompact

WURFL - **W**ireless **U**niversal **R**esource **F**ile

XML - **e**Xtensible **M**arkup **L**anguage