



**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

Rio de Janeiro

March 2011

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## Milene Serrano

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.

### Bibliographic data

Serrano, Milene

Reuse-oriented approach for incremental and systematic development of intentional ubiquitous applications / Milene Serrano; advisor: Carlos José Pereira de Lucena. – 2011.

228 f.: il. (color.) ; 30 cm

Tese (doutorado) – Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Informática, 2011.

Inclui bibliografia

1. Informática – Teses. 2. Engenharia de Software. 3. Desenvolvimento Incremental e Sistemático. 4. Intencionalidade. 5. Computação Ubíqua. 6. Sistemas Multi-Agentes. 7. Engenharia de Domínio das Aplicações Ubíquas. 8. Engenharia de Aplicações Ubíquas. 9. Reutilização de Software. I. Lucena, Carlos José Pereira de. II. Pontifícia Universidade Católica do Rio de Janeiro. Departamento de Informática. III. Título.

CDD: 004

To My Beloved Family:  
My Mom *Elizabeth*,  
My Dad *Antônio*,  
My Sister *Gabriela*,  
My Dear Husband *Maurício*,  
My Mother-in-Law *Dona Elizabeth*,  
My Father-in-Law *Senhor Edson (in memoriam)*, and  
My Sisters-in-Law *Adriana* and *Mariana*.

## Acknowledgments

My most special thanks to my Advisor, Professor Carlos José Pereira de Lucena, for his dedication, cooperation, encouragement and guidance during the development of this research.

Very special thanks to my Family for the tenderness, commitment and affection.

Many thanks to Professors Julio Cesar Sampaio do Prado Leite, John Mylopoulos and Eric Yu for their important contributions as well as for the opportunity to work as a Visiting Research in the Department of Computer Science at the University of Toronto during my PhD.

I am also grateful to my Friends of PUC-Rio for their collaboration and friendship.

My sincere thanks to all Professors and Staff of PUC-Rio for their assistance, especially Professor Arndt von Staa, Vera Sotero, Regina Maria Zanon, Tereza Cristina Moura, Rosane Teles Castilho and Luís Fernando Barbosa.

Many thanks to Professors Hugo Fuks, Vera Maria Benjamim Werneck and Mariano Gomes Pimentel for their participation in my Doctoral Thesis Committee.

Finally, thanks to the sponsors CAPES and CNPq for the financial support.

## Resumo

Serrano, Milene; Lucena, Carlos José Pereira de. **Abordagem Orientada à Reutilização de Software para Desenvolvimento Incremental e Sistemático de Aplicações Ubíquas Intencionais**. Rio de Janeiro, 2011. 228p. Tese de Doutorado - Departamento de Informática, Pontifícia Universidade Católica do Rio de Janeiro.

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

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## List of Abbreviations

- AD (Models) or AD (Discipline) - **A**rchitectural **D**esign (Models) or  
**A**rchitectural **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 - **D**ata **A**ccess **O**bject
- DD (Models) or DD (Discipline) - **D**etailed **D**esign (Models) or **D**etailed  
**D**esign (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  
**R**equirements (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 - **H**ibernate **Q**uery **L**anguage
- I (Discipline) - **I**mplementation (Discipline)
- i\* - **i**Star or **D**istributed **I**ntentionality
- IDE - **I**ntegrated **D**evelopment **E**nvironment
- IFCAUC - **I**ntentional **F**ramework for **C**ontent **A**daptation in **U**biqutous  
**C**omputing **S**ystems
- JADE-LEAP - **J**ava **A**gent **D**evelopment **E**nvironment-**L**ightweight  
**E**xtensible **A**gent **P**latform
- JADEX - **J**ava **A**gent **D**evelopment **E**nvironment **e**Xtension
- 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  
    **R**equirements (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