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# Framework for Content Adaptation in Ubiquitous Computing Centered on Agents' Intentionality and Collaborative MAS*

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**Abstract.** The proliferation of wireless technologies along with the "anywhere/anytime" paradigm presents new scenarios for service provisioning. This scenarios demand novel technological support capable of dynamically allowing adaptability of services according to user location and preferences and devices capabilities. Mobile devices require an appropriate infrastructure that should be able to dynamically consult different profiles to load, update and discard information. This information is the main ally to provide the best service and guarantee user satisfaction. In this context, there are few satisfactory solutions for content adaptation in ubiquitous applications based on the BDI Model. In order to fill this technological gap, we propose a framework for content adaptation centered on agents' intentionality and mobility, goal-orientation and Multi-Agent Systems (MAS).

**Keywords**: Content Adaptation, Ubiquitous Computing, Multi-Agent Systems, Goal Orientation, Agents' Mobility, BDI Model.

**Resumo**. A crescente proliferação de tecnologias sem fio combinada à necessidade de serviços em qualquer lugar e a qualquer momento apresenta novos cenários para o fornecimento de serviços. Esses cenários demandam tecnologias emergentes capazes de dinamicamente permitir a adaptação de serviços de acordo com as preferências dos usuários e capacidades dos dispositivos. Dispositivos móveis requerem uma infraestrutura apropriada que permitida a consulta dinâmica dos diferentes perfis para carregar, atualizar e descartar informações. Essas informações são os principais aliados para prover um melhor serviço de adaptação e garantir a satisfação do usuário. Nesse contexto, existem poucas soluções satisfatórias para adaptação de conteúdo em aplicações ubíquas baseadas no modelo *BDI* (*Belief Desire Intention*). Visando contribuir para esse *gap* tecnológico, propomos um *framework* para adaptação de conteúdo centrado na intencionalidade e mobilidade de agentes, orientação à meta e Sistemas Multi-Agentes (SMA).

**Palavras-chave**: Adaptação de Conteúdo, Computação Ubíqua, Sistemas Multi-Agentes, Orientação à Meta, Mobilidade de Agentes e Modelo BDI.

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# 1 Introduction

The emergent diversity in the capabilities of various mobile devices such as memory, processor and display capabilities and computational power increases the relevance of ubiquitous applications and, consequently, the content adaptation that is intrinsic to these applications. Moreover, the several users' preferences, commonly found in ubiquitous context, also motivate the content adaptation to guarantee the users' satisfaction. Due to this trend, Web remote content servers normally must provide multiple versions of the same content according to demand and based on each client device. Additionally, other profiles must carefully be considered in this context, such as the network and content profiles. These profiles respectively store some important information about the network (e.g. network bandwidth) and the content (e.g. URL and content format).

The existing view that hides important network features and considers services as standalone components is negative for the success of ubiquitous applications since it compromises these applications' performance. On the other hand, the dynamically changing of ubiquitous contexts does not allow that the service remote servers provide several services through different networks for heterogeneous devices. Both solutions commonly result in users' dissatisfaction. Additionally, as another inherent result of this context, users that accesses services using portable limited devices are usually frustrated due to slow service delivery or because they are forbidden to see certain media types. According to a number of researchers [Marques and Loureiro 2004] [Xiaodong et al. 2001] [Han et al. 1998], the alternative is content adaptation.

In order to overcome this complex issue, many research groups [Moraïtis et al. 2003] [Garlan et. Al 2002] [CHAI 2008] have proposed solutions for content adaptation using different technologies (e.g. web service, object-orientation and agent abstraction). According to [Berhe et al. 2004]: *"To meet the demands in this heterogeneous environment, it is necessary for the information to be customized or tailored according to the user's preferences, client capabilities and network characteristics. This tailoring process is called content adaptation."*

However, there is an absence of satisfactory solutions for content adaptation to applications based on the BDI (Belief Desire Intention) model [Braubach et al. 2003]. This model is presented in several scientific works [Tweedale et al. 2007] [Robbinsa and Wallaceb 2007] as an important ally to ubiquitous software development based on intelligent agents, which represent a natural metaphor for human behavior, especially if they are implemented using reasoning and learning techniques [Bigus and Bigus 2001] and goal-orientation [Cysneiros et al. 2005].

Therefore, the development of an appropriate support to fill this technological gap and to improve ubiquitous applications development is necessary. Based on an experimental ubiquitous case study [Serrano et al. 2008a] [Serrano et al. 2008b] and a multi-disciplinary case-study (see Section 4.2.) centered on a collaborative MAS and BDI Model, we proposed a framework for content adaptation in ubiquitous computing, called IFCAUC (Intentional Framework for Content Adaptation in Ubiquitous Computing). Our proposal consists basically of the planning, definition and implementation of a conceptual model for content adaptation considering agents' intentionality [Gold and Sugden 2008], goal-orientation, mobility [Satoh 2005], similarity concept [Andreasen et al. 2003] and context analysis. Furthermore, our main purpose is offered a novel infrastructure to guide the content adaptation in ubiquitous applications, which are coordinated by different intelligent autonomous entities (e.g. cognitive or deliberative agents [McBurney and Parsons 2007]).

The rest of this monograph is organized as follows: Section 2 presents the related work; Section 3 describes the main ubiquitous profiles intrinsic of ubiquitous context; Section 4 briefly presents adaptation categories such as resizing and transcoding; Section 5 shows details of our proposal; and finally, Section 6 summarizes the contributions of this work, presents open questions and directions for further work.

## 2 Related Work

We were particularly inspired by the works presented as follows, since they explore solutions that are used in our work to deal with important ubiquitous issues and content adaptation.

In [Ravindran et al. 2002], the authors present the concept of service personalization in the adaptation scenario, which consists of delivering personalized services based on profile information. In this context, they proposed a framework for managing service personalization in a domain. Additionally, they deal with some challenges and issues documented in a survey that helped us to improve our work. We also studied the service personalization concept using an analogy with content personalization to guarantee users' satisfaction based on agents' intentionality.

In [Wei-Ying Ma et al. 2000], the authors describe a framework that includes content adaptation algorithms, client capability and network bandwidth discovery methods, and a Decision Engine for determining when and how to adapt content. The main goal of their research is to improve content accessibility and perceived quality of offered services. Moreover, they present various content adaptation techniques to improve web accessibility and information delivery through the use of mobile devices.

In [Berhe et al. 2004] an architectural framework of service-based content adaptation centered on a content negotiation and adaptation model is presented. The authors, Berhe, Brunie and Pierson, also deal with the devices' heterogeneity, users' mobility and other challenges for information delivery applications in pervasive environments. Although the infrastructure is flexible, it is not agent-oriented.

It is important to consider that neither the above research nor most of the work commonly found in the literature support content adaptation in ubiquitous applications that are implemented using the BDI Model. In order to fill this technological gap and based on content adaptation State-Of-The-Art [Mohan et al. 1999] [Phan et al. 2002], we propose a conceptual framework for content adaptation in a ubiquitous computing scenario centered on the Multi-Agent Systems paradigm and the BDI Model. Our main contribution is that our conceptual model is mainly oriented to specific ubiquitous issues, which are commonly found in ubiquitous environments. As our proposal is agent-oriented, we also used the agents' intentionality concept and others agents' properties (e.g. mobility, adaptability, flexibility and autonomy) to guarantee, among other things, the users' satisfaction. Furthermore, the proposed model offers some interesting resources that make the proposal unique, such as the use of similarity analysis in the planning of content adaptation to deal with the uncertainness character.

## 3 Ubiquitous Profiles and Adaptation Policy

We cannot think about content adaptation and ubiquitous computing without thinking about profiles. One of the main issues of the content adaptation architecture is the definition of the adaptation policy. This policy comprehends: (i) the choice of adaptation services, which will be offered; (ii) the specification of the locals and remote adapters, which will perform the adaptations; (iii) the determination of when the adaptation can be requested; and (iv) the execution order of the adaptations. To determine the adaptation policy it is necessary to identify some information about ubiquitous adaptation environment such as: the capacities and characteristics of the access devices; the users' preferences and personal data; the communication network conditions; the required content characteristics; and the specifications of the contract between the service server and the final user. This information is respectively described and stored in profiles: device profile, user profile, network profile, content profile and server profile.

Profiles are the main key of an appropriate content adaptation. This notion is intrinsic to ubiquitous computing and commonly applied in the ubiquitous application development [W3C - CC/PP 2008] [Berhe et al. 2004]. Additionally, according to [Claudino et al. 2005] the adaptation environment information can be dynamic or static. The dynamic information (e.g. requested content or network specifications) must be obtained during the adaptation process. The static information (e.g. users' preferences and device capabilities) can previously be defined. Both dynamic and static information are essential to achieve users' goals and to guarantee users' satisfaction. Based on these considerations, our approach uses the profiles notion to facilitate the content adaptation and to provide an adequate conceptual model to guide this adaptation. To improve our approach, we use a collaborative MAS. Cognitive agents are responsible for providing the best service to users and according to the profiles specifications.

## 4 Adaptation Categories

We classified different content adaptations into five main categories: (i) adaptation based on resizing, to adapt the content according to the device screen resolution; (ii) adaptation based on transcoding, to transcode the content from one format to another; (iii) adaptation based on reduction, to adapt the content using data compression; (iv) adaptation based on replacement, to replace a sequence with still frames, which are combined to form a slide show; and (v) adaptation based on integration, to adapt the content using service composition. For example, a video can be obtained by combining different image frames with the corresponding audio.

## 5 Our Proposal

We proposed a conceptual model for content adaptation based on agents' intentionality, goal-orientation, mobility and fuzzy logic. The content adaptation process is divided in some activities: (i) Plan; (ii) Define; and (iii) Implement. We validate our proposal applying it in a ubiquitous case study called DIUP (Dental Informatics Ubiquitous Project). An overview about our proposal is presented in following sections.

## 5.1 Process Activities

Figure 1 illustrates our conceptual framework as a process with three main activities (Plan, Define and Construct). The notation used to represent it is a SADT diagram [Marca and McGowan 1987]. The entries, controls, mechanisms and exits of the process are also presented.

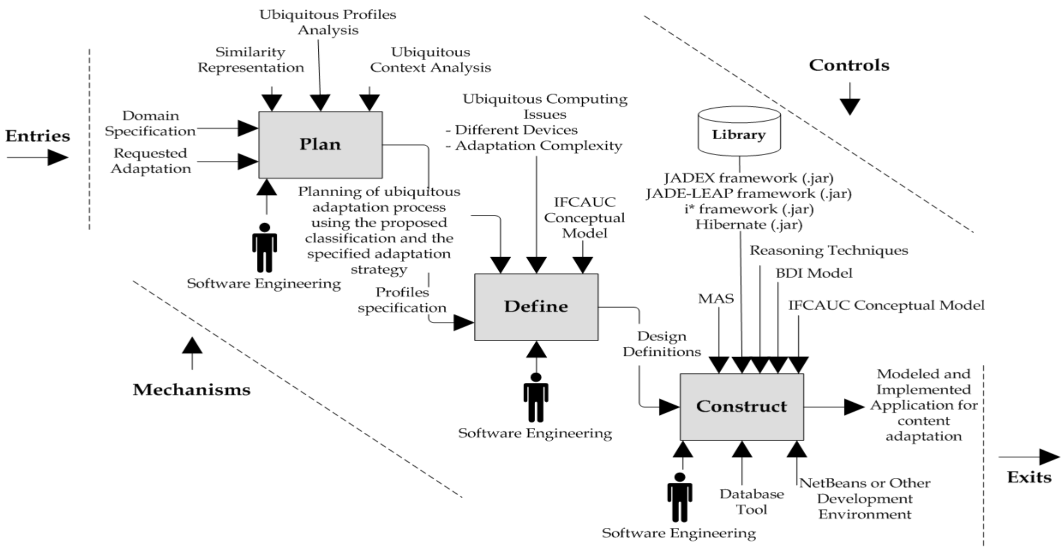


**Figure 1: Conceptual framework for content adaptation represented by a SADT diagram**

First, the domain specification and requested adaptation are the entries of the "Plan" activity. Based on similarity representation, ubiquitous profiles and context analysis, the ubiquitous adaptation process is carefully planned and the profiles are completely specified. Thus, the adaptation is classified according to the difficulty of its performing (represented by predefined fuzzy sets - critical, very high, high, reasonable, low, very low and trivial). This classification is used to establish an adaptation strategy (e.g. critical, moderate and trivial). According to this strategy, the "Define" activity starts. In "Define" activity, the model and architecture design are defined based on the adaptation strategy and controlled by the proposed conceptual model and ubiquitous computing issues. The design definitions are the entries of the last activity "Construct." In the "Construct" activity, we show the modeling and implementation of the adaptation model using some specific mechanisms and technologies (e.g. development environment and database tool) and some important controls (e.g. MAS, goal-orientation, reasoning and learning techniques, BDI Model, the adaptation proposed model and some libraries such as JADEX framework [Pokahr and Braubach 2007]). Finally, the adaptation is modeled and implemented through the IFCAUC frozen-spots and extending its hot-spots.

## 5.2 Case Study Overview

To test and validate our model, we applied it in a ubiquitous case study, called DIUP (Dental Informatics Ubiquitous Project). This project specifically proposes the integration between the informatics and dentists in order to improve dental care to deprived communities through the use of mobile devices. The mobile devices can allow the patient registration, care monitoring, dental diagnosis, drug prescriptions, oral diseases searching, appointments recording and managing, and other important activities intrinsic to dental treatment anywhere and anytime. A collaborative and intelligent Multi-Agent System performs these activities. We were particularly motivated by the authors in [Schleyer et al. 2003]: *"…technology also can provide a solution to many of the routine hassles in dental practice. Well-integrated systems, designed around the work flow of the dental team, can allow care providers to concentrate on what they do best: delivering patient care."*

## 5.3 Content Adaptation Planning Activity

The purpose of this process activity is to plan the content adaptation according to ubiquitous application profiles. We propose the use of the similarity concept and different adaptation strategies that are performed by a collaborative Multi-Agent System.

### 5.3.1 Analysis Model based on Similarity

We propose the use of similarity analysis to understand and to investigate the profiles information involved in DIUP adaptation process. We can say that "Simple Cellular is 30% Computer" and also that "Smartphone is 80% Computer" (see Figure 2). Thus, "Smartphone" is more Computer than "Simple Cellular" according to the similarity concept. We can observe that the diagram is based on the generalization relationship, which establishes a special association between an element and its parents. Our purpose is to use this kind of graphic representation to classify the profiles information and to determine associations among different information according to their similarities. Thus, in our context, similarity means how closer one element is to another.

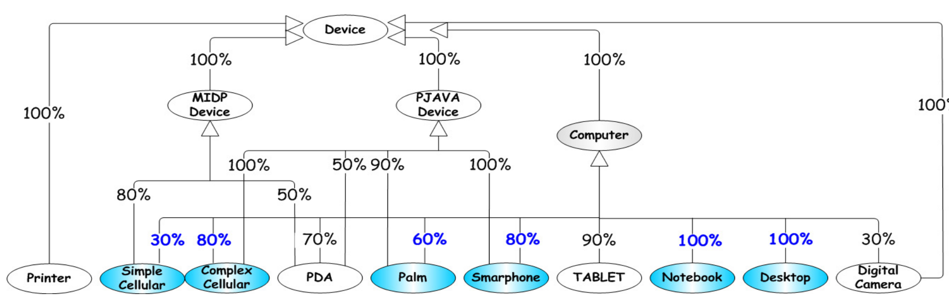


**Figure 2: Example of a Graphic based on Similarity Concept**

The best case to perform the adaptation is determined using the statistical and probabilistic data according to the profiles. For us, the best case means the best profile behavior to perform the adaptation and guarantee its full success. In the DIUP case study, we determine that "The best device profile to perform content adaptation is closer to computer features."

Each DIUP profile is analyzed based on the proposed representation to statistically define how they are closer to the defined best case. The DIUP device profile is composed of: 2% simple cellular; 90% complex cellular; 5% palm; 5% smartphone; 10% notebook; and 10% desktop. Thus, we can partially conclude that most of the DIUP devices will be complex cellular and other devices (e.g. notebook and desktop) that are closer to computer features (e.g. high memory and processing capacity).

Additionally, we can determine how more difficult the adaptation process is for DIUP domain based on the predefined fuzzy sets:

(i) **Critical (0 – 15%),** the adaptation process can have serious problems to be performed. The process has to be carefully planned, managed and implemented. Some tests are also indicated to guarantee all the process;

(ii) **Very High (15 – 30%),** the adaptation process can be very difficult to be performed. A well-prepared plan is recommended;

(iii) **High (30 – 45%),** the adaptation process is difficult to be performed. It is necessary to worry about limited devices (e.g. simple cellular); (iv) **Reasonable (45 – 60%),** the adaptation process has an acceptable difficulty. The IFCAUC can guide the adaptation if the application is intentionally agent-oriented;

(iv) **Low (60 – 75%),** the adaptation process is easy to be performed. Probably the device profile is closer to computer features. However, it is important to use a model to deal with some particular ubiquitous issues;

(v) **Very Low (75 – 90%),** the adaptation process is very easy to be performed. Probably the device profile is very much closer to computer features. However, it is important to consider adaptation to improve users' satisfaction;

(vi) **Trivial (90 – 100%),** the adaptation process is trivial to be performed. The content adaptation is quite direct.

In DIUP analysis, we can finally conclude the DIUP content adaptation is "very easy" to be performed since predominant use of complex devices is found in this environment. These devices, for example, have the capacity to run complex technologies and high image resolution. However, content adaptation has to be performed to guarantee users' satisfaction. According to the results of the DIUP experience, we believe the proposed similarity analysis is promising since it improves the ubiquitous requirements analysis; allows the elicitation of profiles; and previously determines the difficult to perform content adaptation.

### 5.3.2 Different Adaptation Strategies

Based on the results of the analysis using the proposed model and the comparison using the proposed fuzzy sets, we suggest some strategies to perform the content adaptation:

(i) **Critical Strategy**, it means that the adaptation difficulty is considered very high or critical. In both cases, a collaborative MAS could be monitored by human intervention combined with a detailed planning, manager, implementation and tests to deal with the problem. The collaborative MAS can be physically located in a unique application server to facilitate its control. The use of a dedicated adaptation server to avoid the ubiquitous application server overload is highly recommended. Additionally, an expert, who can intervene to avoid critical mistakes, must control the content adaptation;

(ii) **Moderate Strategy**, it means that the adaptation difficulty is considered high, reasonable, low and very low. In all these cases, a collaborative MAS, which is physically located in the application server, can solve the problem. Some reasoning and learning techniques can be applied to improve the adaptation or even the use of a dedicated server to avoid the ubiquitous application server overload. The agent-oriented intentional applications, which adaptation process can be performed by a moderate strategy, are the main candidates to use our adaptation proposal; and

(iii) **Trivial Strategy**, a reactive agent society can solve the problem and the content adaptation could be dispensable.

More details about these strategies and our proposal are presented in Sections 5.4 and 5.5. All remain adaptation process is dependent on strategy choice. In other words, the planning activity directly reflects in definition and construction activities.

## 5.4 Content Adaptation Definition Activity

In critical and moderate strategies, we argue that it is more appropriate to use a dedicated server to perform the adaptation activities. We base our proposal on two considerations: (i) to perform adaptation activities on the application server can be appropriated in simple applications, in which the adaptations are not complex. However, ubiquitous applications are commonly dependent on several adaptations, which can definitely overload the application server; (ii) to perform adaptation activities on the devices is a challenge nowadays [Zufferey and Kosch 2006]. The main problem is the few memory and processing capacities of some devices, which cannot support complex adaptation processes.

Motivated by those considerations and according to the adaptation strategy choice, we emphasize the importance of using a dedicated adaptation server. This design decision improves the adaptation process in complex ubiquitous contexts and it is appropriated to guarantee the users' satisfaction.

Unfortunately, the use of a dedicated server to perform adaptation activities has some problems that avoid the full success of this design solution. The main problem is the communication overhead since several content requests can be sent at the same time. The control of this information is not trivial. Thus, we suggest the use of a collaborative Multi-Agent System to improve this communication.

The use of reasoning, learning and various knowledge bases are also proposed in our adaptation process. In this scenario, the Multi-Agent System can delegate the content adaptations to different mobile agents, each of them with its own knowledge base. These agents can migrate to different dedicated adaptation servers to perform the adaptations and return to the application server to send the adapted contents to client devices. Furthermore, we conclude that this adaptation process is invisible to the clients. It contributes to full users' satisfaction since the process complexity (e.g. communication protocols) is delegated to different agents, which are responsible to achieve users' goals.

## 5.5 Content Adaptation Construction Activity

The modeling and implementation of our proposal is centered on goal-orientation modeling [Yu 1998], agent mobility; collaborative Multi-Agent System; agents' intentionality and reasoning techniques. Details of these concepts are presented in Sections 5.5.1. to 5.5.4.

### 5.5.1 Goal-Orientation Modeling through the Use of i*Framework

According to [Alencar 1999], i* (Distributed Intentionality) [Yu 1998] has some important features: (i) deals with intentional properties of an agent and also the intentional relationship among different agents; (ii) presents descriptive models, assuming that the behavior of a strategic agent can be completely open and unpredictable; and (iii) has a semi-formal component, including concepts such as satisfaction, which are not prepared to be formalized.

We used the i* framework to model IFCAUC agents based on their intentionality. Some advantages of using i* framework are, for example, the reduction of the complexity of the commonly used diagrams [Bauer and Odell 2005] [Silva and Lucena 2003]; and the modeling of functional (e.g. goals, tasks, subgoals and subtasks) and non-functional requirements [Chung et al. 2000] centered in goal-orientation that enhances the possibility of implementing traceability policies. i* uses two diagrams to model the application requirements: (i) the Strategic Dependency (SD) Model, which describes the dependency relationships among actors/agents in an organizational context, and (ii) the Strategic Rationale (SR) Model, which describes the stakeholders' interests and how they might be addressed by different software specifications. To illustrate a Strategic Rationale model, consider part of the IFCAUC Adaptation Mediator Agent modeling, presented in Figure 3.

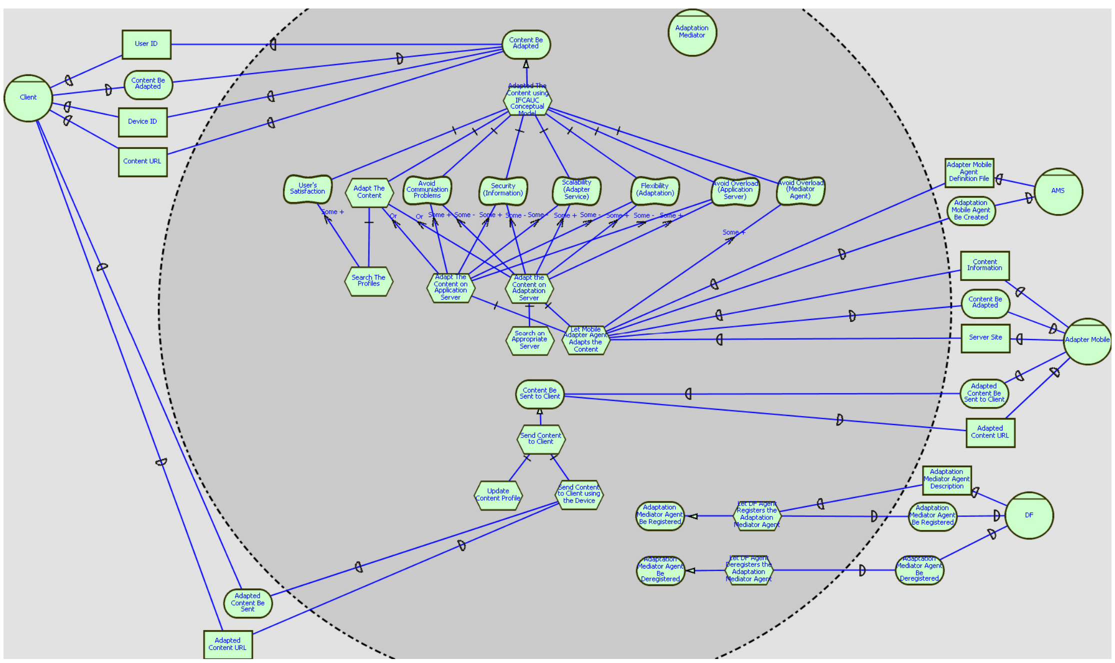


**Figure 3: IFCAUC Adaptation Mediator Agent Modeling using Distributed Intentionality**

Firstly, we model the IFCAUC adaptation process using specific agents such as "DF Agent," "AMS Agent," "Adaptation Mediator Agent," "Mobile Adapter Agent" and "Adapter Agent" and two main smart-spaces, "Application Server" and "Adaptation Server." "Mobile Adapter Agent" is also a mobile autonomous entity. We can also have more than one "Adaptation Server." In order to simplify the representation, we only considered one "Adaptation Server."

The goal of the adaptation process is "Content Be Adapted." We established a way to achieve this goal using the task "Adapt the Content." To perform this task, we use the task decomposition and some sub-tasks are specified: "Search the Profiles," "Adapt the Content on Application Server" and "Adapt the Content on Adaptation Server." To perform this last option, it is necessary to "Search an Appropriate Server" in Yellow Pages. Thus, the "Adaptation Mediator Agent" consults the "DF Agent." The "Adaptation Mediator Agent" delegates the adaptation ("Let Mobile Adapter Agent Adapt the Content") to "Mobile Adapter Agent" informing the "Sever Site" and the "Content Information." The "Mobile Adapter Agent" is created by the "AMS Agent." Thus, the "Mobile Adapter Agent" has to achieve the goal "Content Be Adapted" associated to the task "Adapt the Content." To perform this task, the "Mobile Adapter Agent" migrates to the "Adaptation Server" smart-space. It collaborates with "Adapter Agent" to achieve the goal "Content Be Adapted," passing the "Content." The content is adapted and the "Mobile Adapter Agent" returns to "Application Server" smart-space. The knowledge base is updated using learning techniques. The content adaptation process finishes when the "Adaptation Mediator Agent" sends the adapted content to the user through her/his device.

### 5.5.2 Agents' Mobility and a Collaborative Multi-Agent System

Considering the adaptation process will be performed on a dedicated server, which will be located in another smart-space that is different than the smart-space of the application server, we propose the use of a mobile agent to support several activities that are intrinsic to this complex adaptation process. Mobility is an agents' property that allows the migration from one smart-space to another. To migrate, the mobile agent must previously store its state; requests its application server go out and its adaptation server go in. The adaptation is performed and the mobile agent will return to the application server, recovering its state and updating the content profile. Figure 4 illustrates all proposed processes needed to perform content adaptation in ubiquitous contexts.

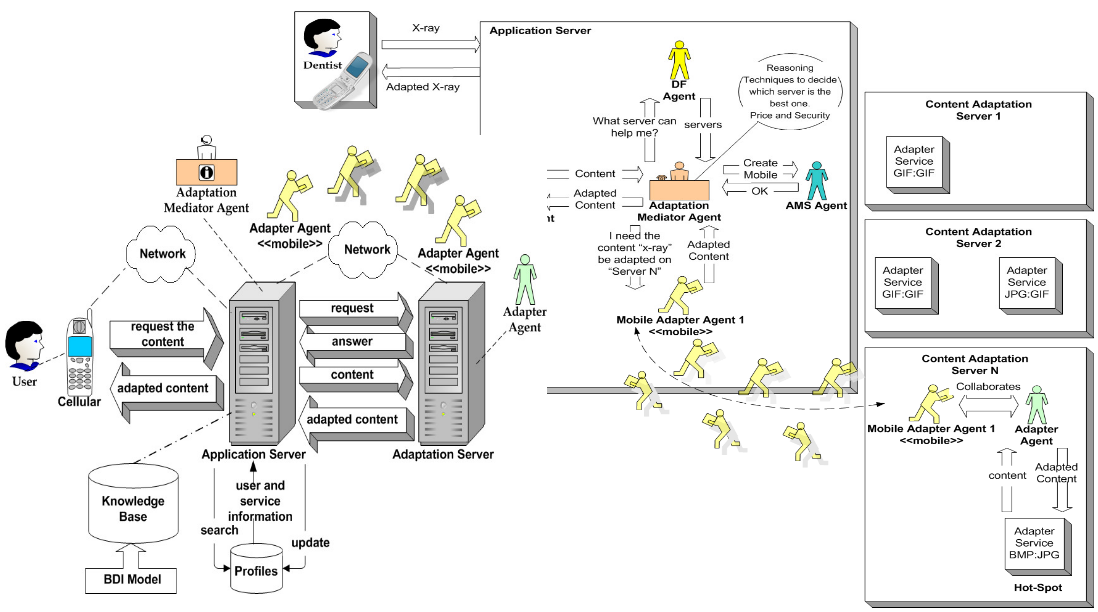


**Figure 4: Proposed Content Adaptation Model Overview**

The user requests the desired content using a portable device and the wireless network. A collaborative multi-agent system receives the request and an adaptation mediator agent is declared responsible for this content adaptation. This agent first consults its knowledge base to search the content. If this alternative fails, then it is necessary to consult the profiles. Information about the user's preferences and her/his device capacities are received. Moreover, the mediator adaptation agent delegates the adaptation content to a mobile adapter agent that migrates to a dedicated adaptation server with the profiles information. Based on this information, the content is adapted using collaboration and reasoning techniques (see 5.5.4) between mobile adapter and adapter agents. The mobile adapter agent returns with the content to the application server. The user receives the content according to her/his preferences and device features. Additionally, we also deal with the absence of a specific adaptation server capable of adapting some content. If no adapters are compatible with the specified profiles - for instance, if there are no content request results – the model suggests that a content unavailability message be sent to the device client.

### 5.5.3 Agents' Intentionality

The JADEX Project is conducted at the Hamburg University [Pokahr and Braubach 2007]. It consists of a framework that includes various tools for runtime and debugging activities as well as for the development and documentation of the solutions found. The JADEX main proposal consists of extending the JADE Platform using the reasoning concept and the BDI Model. JADEX is an implementation of a reactive and deliberative agent architecture for representing mental states following the BDI Model. Messages deliberate reactions that instantiate plans based on Plan Library. The Plan is selected and executed. Frequently, new goals are adopted and the Belief Base is consulted. When the plan is running, it dispatches goals, sub-goals and events, as internal events or message events. Tasks are associated to plans. Task is i* representation in modeling abstraction level and Plan is JADEX BDI representation in implementation abstraction level.

Centered on plans deliberation, goals, beliefs and events, the BDI Model is viewed as appropriate to implement a complex ubiquitous application based on the Multi-Agent Systems paradigm and goal-orientation, since it represents the agents' society – agents' reactions and reasoning - as a natural metaphor for human behavior. This natural association inspired us to develop an adaptation infrastructure to improve the use of this model.

The agents of our collaborative multi-agent system can dynamically decide to perform some adaptation strategy according to the ubiquitous context. Our agents are prepared to perform adaptations based on resizing or transcoding. In adaptation based on resizing, the agents' main goal is to adapt the content according to the device screen resolution. MIDP devices have low capability. Personal JAVA devices have medium capability. Powerful devices have high capability. In adaptation based on transcoding, the agent's main goal is to adapt (type conversion) the content according to: (i) users' satisfaction (e.g. type desired by user obtained in user profile); or (ii) device compatibility (e.g. type accepted by device obtained in device profile). Figure 5 illustrates both agents' adaptation strategies pyramids.

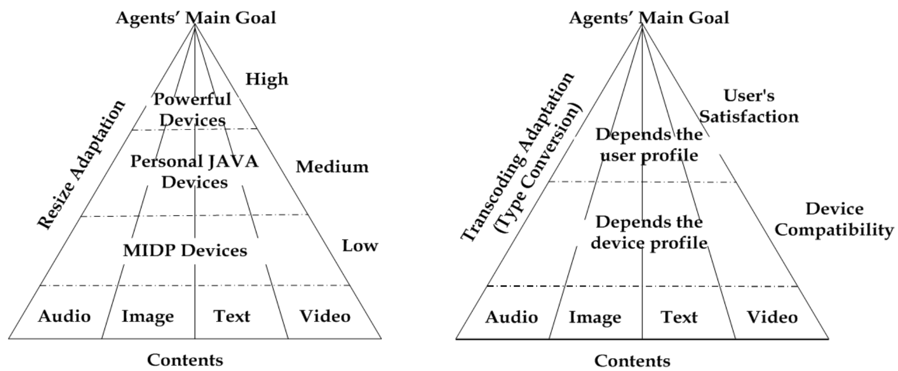


**Figure 5: Agents' Adaptation Strategies Pyramids**

### 5.5.4 Reasoning Techniques

To provide reasoning capability for deliberative or cognitive agents, we combine the use of the BDI Model and Fuzzy Logic. The formal concept of a fuzzy set was introduced by Zadeh [Zadeh 1965]. In the fuzzy set theory, each set element has a pertinence degree and it is appropriated to be used with uncertainty. Thus, we consider that fuzzy logic was the best way to classify and to analyze service proposals, based on fuzzy information that is exchanged between the agents.

Our "Adaptation Mediator Agent," for example, analyzes dedicated adaptation servers using several fuzzy conditional rules and reasoning techniques to decide which server is considered the best. To combine all the rules and to perform the analyses, we use the BDI Model and a Fuzzy Logic Library [Bigus and Bigus 2001]. The adaptation mediator agent, for example, considers the price and security. Thus, using conditional rules, this agent establishes the proposal quality values and decides which server is the best to satisfy the user request.

## 5.6 Extending IFCAUC – Frozen-Spots and Hot-Spots

Our main goals are: (i) to allow the reuse of good adaptation solutions either in design or implementation activities; (ii) to avoid the code replication; (iii) to optimize the adaptation process modeling; and (iv) to facilitate the specialization of our generic model. Motivated by these goals, we proposed the use of generalization in plan abstraction. We used plans generalizations to represent and implement the hot-spots of IFCAUC. We have generic plans, which are composed of tasks sets to perform the content adaptation. Users that are interested in instantiated IFCAUC must extend these plans to implement specific plans.

Generic plans have abstract methods and attributes, which must be implemented by an instance. The instance can use specific adaptation services to perform specific content adaptations according to the necessities – its specific goals. For example, the content can be an image or a text or a sound. In all these cases, the generic plan is extended to represent specific plans, which are respectively a set of tasks to perform image, text and sound adaptations.

## 5.7 Running the DIUP Application

The DIUP application extends IFCAUC hot-spots to deal with different contents (e.g. image and video), heterogeneous devices and users' mobility. To test the DIUP application running, we describe some specific scenarios to show, for example, the adaptation (e.g. type conversion and resizing) according to different devices features. Figure 6 illustrates this process. In this case, the desired image (x-ray) was 473 x 640 in a PNG format; the device has a screen 240 x 320 and only accepted JPG format; and the user desired JPG format. Thus, an adaptation to convert PNG to JPG format and a resizing to convert 473 x 640 to 240 x 320 are necessary.

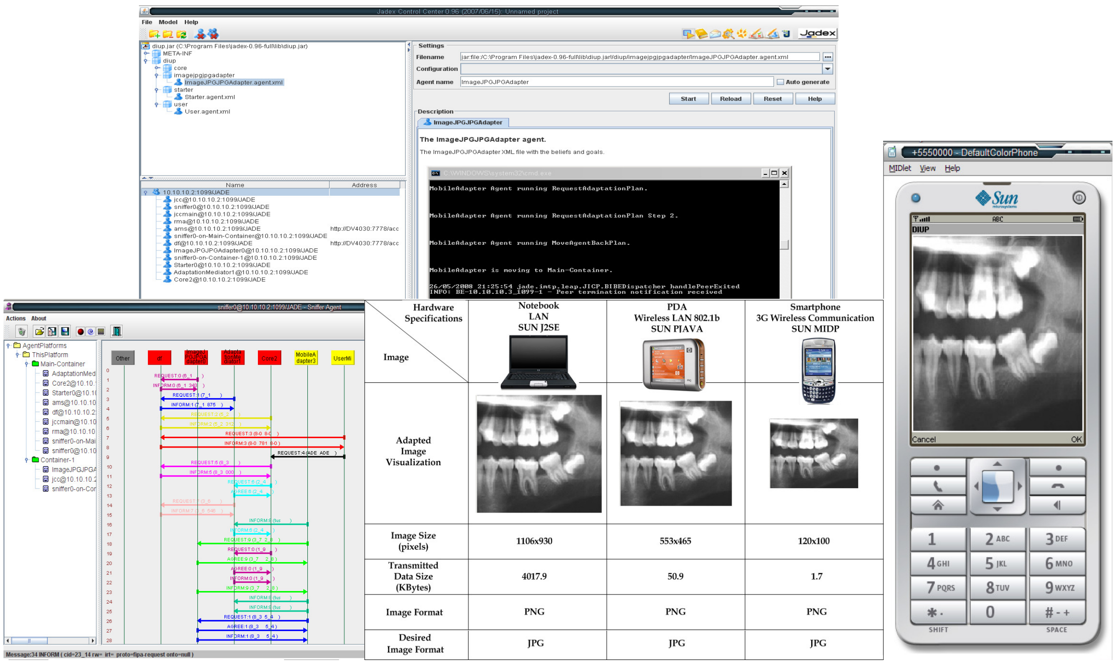


**Figure 6: DIUP Running**

# 6 Conclusions, Open Questions and Future Work

The proliferation of wireless technologies along with the "anywhere/anytime" paradigm presents new scenarios for service provisioning. This scenarios demand novel technological support capable of dynamically allowing adaptability of services according to user location and preferences, devices capabilities and network bandwidth. Mobile devices require an appropriate infrastructure that must support the devices accessibility to traditional (e.g. services previously designed to desktop computers) and new services (e.g. services specifically designed to portable devices). Moreover, it should be able to dynamically consult different profiles. This information is the main ally to guarantee user satisfaction.

In this context, we have various research groups that investigate solutions to adapt content. However, there are few satisfactory solutions for content adaptation to ubiquitous applications based on the BDI Model. Since this model is viewed as appropriate to implement complex ubiquitous applications based on Multi-Agent Systems and goal-orientation, it increases the importance of considering an appropriate BDI-oriented infrastructure to deal with adaptability in ubiquitous context.

Motivated by the fact that few technological supports deal with content adaptation for ubiquitous applications based on agents' intentionality, we propose the IFCAUC centered on a collaborative MAS. Additionally, we show some contributions that make our proposal unique such as: (i) planning solutions using an analysis model based on similarity; (ii) design solutions mainly based on the use of a dedicated adaptation server and some adaptation strategy (critical, moderate or trivial); (iii) construction solutions centered on a collaborative MAS; goal-orientation modeling and implementation, BDI Model and agents' properties (e.g. mobility, collaboration, autonomy, flexibility and adaptability).

As showed in this paper, IFCAUC offers solutions that may find immediate use in ubiquitous application development processes giving support to deal with the inherent content adaptation challenge. The evidence for the power of IFCAUC is provided through the DIUP case study. Of course, many studies have to be done to further refine our proposal. Some interesting refinements can improve the service and content adaptation using personalized delivering. In this context, we find different possibilities that could be explored such as: advertising insertion; dynamic content composition; text/word translation and others. These are some examples of open questions that will be investigated in further work.

## References


Andreasen, T.; Bulskov, H.; Knappe, R. (2003) "From Ontology over Similarity to Query Evaluation." Elsevier Science, CES'03, December.

Alencar, F. (1999) "Mapeamento e modelagem organizacional em especificações precisas." PhD Thesis. Universidade Federal de Pernambuco, December.

Bauer, B.; Odell, J. (2005) "UML 2.0 and agents: how to build agent-based systems with the new UML standard." Engineering Applications of Artificial Intelligence, vol. 18, issue 2.

Berhe, G.; Brunie, L.; Pierson, J. M. (2004) "Modeling Service-Based Multimedia Content Adaptation in Pervasive Computing." ACM CF'04, ISBN:1-58113-741-9, pp. 60-69, Italy, April.

Bigus, J.; Bigus, J. (2001) "Constructing Intelligent Agents Using Java." Second Edition. Ed. John Wiley & Sons Incorporated, 2 Edition, 432 pages, ISBN 978-0471396017.

Braubach, L.; Lamersdorf, W.; Pokahr, A. (2003) "Jadex: Implementing a BDI Infrastructure for JADE Agents." University of Hamburg, vol.3, n.3, pp.76-85, September.

CHAI – Group Home Page. Accessed at: http://chai.it.usyd.edu.au/index.cgi?Context=Home (2008)

Chung, L. K.; Nixon, B. A.; Yu, E.; Mylopoulos, J. (2000) "Non-Functional Requirements in Software Engineering." Kluwer Publishers, vol.5, 472 pages, ISBN 978-0-7923-8666-7.

Claudino, R. A. T.; Souza, W. L.; Prado, A. F. (2005) "Uma Arquitetura para Adaptação de Conteúdo na Internet." Proceedings of the 23nd Brazilian Symposium on Computer.

Cysneiros, L. M; Werneck, V.; Amaral, J.; Yu, E. (2005) "Agent/goal Orientation versus Object Orientation for Requirements Engineering: A practical Evaluation Using an Exemplar." WER'05.

Garlan, D.; Siewiorek, D.; Smailagic, A.; Steenkiste, P. (2002) "Project Aura: Towards distraction-free pervasive computing." IEEE Pervasive Computing, vol.1, pp.22–31.

Gold, N.; Sugden, R. (2008). "Theories of team agency." Oxford University Press, Book Chapter, ISBN13: 9780199287260, No. 12. (To appear in Rationality and Commitment).

Han, R.; Bhagwat, P.; LaMaire, R.; Mummert, T.; Perret, Rubas, J. (1998) "Dynamic adaptation in an image transcoding proxy for mobile Web browsing." IEEE Personal Commun., 5(6):8–17, December.

Marca, D. A.; McGowan, C. L. (1987) "SADT: structured analysis and design technique." McGraw-Hill, ISBN:0-07-040235-3, 392 pages, New York, NY, USA.

Marques, M.; Loureiro, A. (2004) "Adaptation in mobile computing." SBRC'04, pp. 439-452, RS.

McBurney, P.; Parsons, S. (2007). "Retraction and Revocation in Agent Deliberation Dialogs." Springer Netherlands, vol. 21, No. 3, pp. 269-289, September.

Mohan, R.; Simth, J. R.; Li, C. S. (1999) "Adapting multimedia internet content for universal access." IEEE Transactions on Multimedia, 1(1):104–114, March.

Moraïtis, P.; Petraki. E.; Spanoudakis, N. I. (2003) "Engineering JADE Agents with the Gaia Methodology." Dep. of Computer Science, University of Cyprus, Springer Berlin, pp.77-91.

Phan, T.; Zorpas, G.; Bagrodia, R. (2002) "An Extensible and Scalable Content Adaptation Pipeline Architecture to Support Heterogeneous Clients." In Proceedings of ICDCS'02, July.

Pokahr, A. and Braubach. L. (2007) "JADEX Tutorial." Distributed Systems Group, University of Hamburg, Germany, Release 0.96 - Last Update: June.

Ravindran, G.; Jaseemudin, M.; Rayhan, A. (2002) "A management framework for service personalization." 5°. IFIP/IEEE International Conference on MMNS'02, USA.

Robbinsa, R. W.; Wallaceb, W. A. (2007) "Decision support for ethical problem solving: A multi-agent approach." Decision Support Systems, vol. 43, Issue 4, pp. 1571-1587, August.

Satoh, I†. (2005) "Mobile Applications in Ubiquitous Computing Environments." Mobile Applications in Ubiquitous Computing Environments, IEICE, vol.E88–B, n.3, pp.1026-1033, March.

Schleyer, T. K. L.; Spallek, H.; Bartling, W. C.; Corby, P. (2003) "The technologically well-equipped dental office." JADA, vol. 134, January.

Serrano, M.; Serrano, M.; Lucena, C. J. P. (2008[a]) "Engineering Multi-Agent Systems for Design and Implementation of Ubiquitous Computing." Monograph 10/08, PUC-Rio, 25 pages, March.

Serrano, M.; Serrano, M.; Lucena, C. J. P ; Leite, J. C. S. P. (2008[b]) "Modeling Ubiquitous Applications based on Agent's Intentionality and Multi-Agent Systems." Monograph 13/08, PUC-Rio, 25 pages.

Silva, V. T.; Lucena, C. J. P. (2003) "From a Conceptual Framework for Agents and Objects to a Multi-Agent System Modeling Language." AAMAS'03, Kluwer Academic Publishers.

Tweedale, J.; Ichalkaranje, N.; Sioutis, C.; Jarvis, B.; Consoli, A.; Phillips-Wren, G. (2007) "Innovations in multi-agent systems." JNCA, vol. 30, issue 3, pp. 1089-1115, August.

Wei-Ying Ma, Wei-Ying; Bedner, I.; Chang, G.; Kuchinsky, A.; Zhang, H.† (2000) "A framework for adaptive content delivery in heterogeneous network environments." Multimedia Computing and Networking, vol. 3969, pp. 86-100, San Jose, CA, January.

W3C - CC/PP: Structure and Vocabularies. Accessed at: http://www.w3.org/Mobile/CCPP (2008)

Xiaodong F.; Weisong, S.; Akkerman, A.; Karamcheti, V. (2001) "CANS: Composable, Adaptive Network Services Infrastructure." Proceedings of USENIX'01.

Yu, E. S. K. (1998). "Towards Modelling and Reasoning Support for Early-Phase Requirements Engineering." Faculty of Information Studies, University of Toronto, Canada.

Zadeh, L. A. (1965) "Fuzzy sets. Information and Control." Vol.8, pp.338-352.

Zufferey, M. Kosch, H. (2006) "Semantic Adaptation of Multimedia Content." ELMAR'06, ISSN: 1334-2630, pp. 319-322, June.