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# A multi-agent approach for provisioning of e-services in u-commerce environments

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## Abstract

**Purpose** – Taking into account the importance of e-commerce and the current applications of AI techniques in this area, this research aims to adequate the design of a multi-agent system for the provisioning of e-services in u-commerce environments. This proposal is centred on the methods of evaluation in a u-e-commerce environment.

**Design/methodology/approach** – The multi-agent systems (MAS) approach is based on an MAS model developed for AmI that has been redesigned to support u-commerce. The use of a recommendation system, previously developed by the research group, is suggested for this MAS. The methodological proposal centres on the evaluation of this type of system.

**Findings** – The evaluation of this type of system is the principal problem of current research. Therefore, this is the main contribution of the paper.

**Research limitations/implications** – The different evaluation methods that are proposed, whether qualitative or quantitative, offer the possibility of measuring the added value that the context can give to the use of e-services in different domains of application. Qualitative evaluation should consider the customer as a central piece in the system. In addition, quantitative methods should objectively evaluate the contribution of context to the application.

**Practical implications** – At present, there is no single method for evaluating the benefits of different u-commerce systems, so a new method needs to be found based on these techniques.

**Originality/value** – The research proposes an MAS designed for u-commerce domains, analyzes the capacity of trust management techniques in this environment, and proposes several evaluation methods to show the benefits of context information in the use of e-services. Several real developments are described to show the different applications of MAS in u-commerce and how evaluation is carried out.

**Keywords** Applications, Trust, Management

**Paper type** Research paper

## 1. Introduction

Owing to advances in communication technologies, such as sensor networks and radio frequency identification (RFID), ubiquitous computing is increasingly entering all aspects of life and in all sectors, opening a world of unprecedented scenarios where customers interact with electronic devices embedded in environments that are sensitive to the presence of users (Lyytinen and Yoo, 2002). These environments combine ubiquitous information, and communication, with enhanced personalization, natural interaction and intelligence (Russell *et al.*, 2005). The use of this context offers the possibility of tailoring a new type of advanced applications.

Owing to the evolution of ubiquitous computing technologies, it is possible to augment our everyday environments with abundant ways to access information. There is a great deal of background research on architectures and prototypes of ubiquitous computing. First, the pioneering work at Xerox Parc and at AT & T Labs in Cambridge (Watson *et al.*, 2002), both of which emphasize deploying infrastructures to facilitate ubiquitous computing applications. There is also the Guide and Cooltown Fhg (Addlesee *et al.*, 2001), which focuses more on creating ubiquitous computing applications and deploying them in large user communities. The MediaCup project (Cheverst *et al.*, 2000) at Karlsruhe is another one, which explores the issue of deployment in everyday artifacts and many more. But there is an important difference between the ubiquitous computing systems mentioned previously and those in which ubiquitous environments provide a mechanism whereby commercial activity can be initiated in a seamless and transparent manner (i.e. those systems closely related to ubiquitous commerce) (Watson *et al.*, 2002; Junglas and Watson, 2006; Galanxhi-Janaqi and Nah, 2004). The difference lies in the fact that the latter needs to maximize the benefit to the customer due to the economic interchange generated. When using these kinds of systems, a transactional act is carried out by the customer, in order to access those services, which providers are able to offer.

The evolution of e-commerce into m-commerce is leading to a world of ubiquitous commerce (u-commerce). The trend is for ubiquitous universal access via multipurpose terminals over sensor networks or RFID technology, which have the ability to identify, track and trace objects automatically, permitting the delivery of content over any network (Asif and Mandviwalla, 2005; Ohkubo *et al.*, 2005). Context is a central key in ubiquitous commerce (Coutaz *et al.*, 2005). This content delivery can be adapted to the unique context of the person, the time, the place and the network and can act in unison in order to support smarter and more intelligent delivery (Lyytinen and Yoo, 2002; Russell *et al.*, 2005). This trend was named u-commerce and is facilitated by the emergence of four u-forces: ubiquity, universality, uniqueness and unity. Watson defines u-commerce as the use of ubiquitous networks to support personalized and uninterrupted communications and transactions between an organization and its various stakeholders to provide a level of value over, above and beyond traditional commerce (Watson *et al.*, 2002).

The trend toward u-commerce does not represent simply a change in the way customers access, and use information. In the end it will have a profound effect on the way customers use services, enabling new classes of services that only make sense by virtue of being embedded in the environment.

The twenty-first century is rapidly becoming ubiquitous and systematic to suit individuals, and intelligent agents offer another benefit when they are considered in the context of u-commerce. This system needs an organization similar to the one envisaged by artificial agent societies. If we assume that agents are abstractions for the interaction within a ubiquitous, intelligent environment, one aspect that we need to ensure is that their behavior is regulated and coordinated. Nevertheless, society is there not only to regulate behavior but also to distribute responsibility and contextual information among the member agents (O'Hare *et al.*, 2004) advocate the use of agents as key enablers in the delivery of ambient intelligence and ubiquitous environments.

There are several approaches to intelligent agents in the field of e-commerce; they are distinguished by their inherent characteristics: autonomy, reactivity, proactivity

and mobility. Thus, intelligent agents represent a logical choice for using intelligence in the u-commerce applications. The challenge, therefore, comes from the idea of offering an intuitive and conceptually simple model in which customers can achieve the objective of receiving the adequate service as they are paying for it.

As the next generation business model, u-commerce immediately triggered a lot of attention among enterprises. To facilitate the correct provisioning of u-commerce services, it is important to have a proper evaluation method that can take into account the user's feedback.

In this research we propose MAS designed for u-commerce domains, analyze the capacity of trust management techniques in this environment and propose several evaluation methods to show the benefits of context information in the use of e-services. There are several evaluation techniques proposed in literature for ubiquitous systems (Schmidt, 2002), but there is no established evaluation framework. That is why the principal aim of this research is to provide a proper evaluation system that would take customer feedback into account.

The main contributions of this work are:

- Effectively adapting the design and architecture of an agent-based system developed in previous works (Beigl *et al.*, 2001; Sanchez-Pi *et al.*, 2008a), in order to provide context-awareness and situation sensitivity so that e-services and recommendations, which are suitable to his location, geographical context, communication context preferences and needs can be discovered, processed and provided to the customer (Young, 2002);

- Modifying and instantiating the ontology designed in Sanchez-Pi *et al.* (2008a) in order to support e-services provisioning in u-commerce environments; and

- Developing an evaluation system for a u-commerce environment: a shopping mall, which provides user feedback into the system. We introduced an on-line customer evaluation into the system that is complemented with the off-line feedback.

Following this introduction, the remainder of the paper is organized as follows. Section 2 describes aspects related to ubiquitous computing and the agent's paradigm; a description of the state-of-the-art in these areas is provided. Section 3 describes the MAS architecture and ontology adaptation for a u-commerce environment, as well as a reputation system for providing u-services to customers. Section 4 presents a brief background on evaluation techniques and, finally, our approach to managing customer evaluations is presented. Section 5 shows a practical implementation of the evaluation system for a particular u-commerce scenario: a shopping mall. Finally, our conclusions are presented.

## 2. Ubiquitous computing and agent's paradigm
Ambient Intelligence (AmI) is the paradigm used to equip environments with advanced technology in order to create an ergonomic space where customers can interact with their digital environment in the same way they interact with each other (Aarts *et al.*, 2001). It is also associated with a society based on unobtrusive, often invisible interactions among customers and computer based services taking place in a global computing environment (Kovács and Kopácsi, 2006). Services in AmI will be ubiquitous in that there will be no specific bearer or provider but, instead, they will be

associated with a variety of objects and devices in the environment, which will not bear any resemblance to computers. Customers will interact with these services through intelligent and intuitive interfaces embedded in these objects and devices, which, in turn, will be sensitive to what customers need.

Ubiquitous computing offers many varied applications but will probably have its greatest impact on everyday activities. The essence of the definition is understood through Weiser's (1991) words "The most profound technologies are those that disappear" (Fuentes *et al.*, 2007). The anytime/ anyplace principle of ubiquitous computing emerges as the natural result of research and technological advances in wireless and sensor networks, embedded systems, mobile computing, distributed computing, agent technologies, autonomic computing and communication. Ubiquitous computing paradigm integrates computation into the environment. For ubiquitous computing to work efficiently and transparently, it is essential to have some knowledge of the customer. This is when the customer context needs to be considered (Dey and Abowd, 2000) define context as "any information that can be used to characterize the situation of entities (i.e. whether a person, place or object) that are considered relevant to the interaction between a customer and an application, including the customer and the application themselves".

Context and context-awareness are also central issues to ambient intelligence. The main goal of context-aware computing is to acquire and utilize information about the context to provide appropriate services to the customers at the right time and at the right place. Context-aware applications are a large and important subset of the overall set of ubiquitous computing applications, and have already demonstrated the advantages gained from the ability to perceive the surrounding environment (Hess *et al.*, 2002; Yau and Karim, 2004; Biegel and Cahill, 2004). There are numerous approaches in context- aware applications but most of the available applications are designed for working on specific domains.

A good point seen on the AmI vision is that the electronic or digital part of the ambience (devices) will often need to act intelligently on behalf of customers (Youll *et al.*, 2000). These components will need to be both reactive and proactive, behaving as if they were agents that act on behalf of customers. AmI meets the requirements for the utilisation of agents' technology for the delivery of ubiquitous services, continuous communications and intelligent user interfaces, where different users are empowered by interacting with an environment that is aware of their presence and context, and is able to provide them with personalized services.

We can find several approaches developing platforms, frameworks and applications for offering context-aware services in ubiquitous computing where intelligent agents technology has been applied in order to provide the right information at the right time to its customers. Tourism, healthcare, education, transportation, etc. are some of the sectors where been developed context-aware systems and applications have been developed.

Such applications include location-based services like mapping and points of interest searches, travel planning and, recently, pushing information and events to the customer. Works like the ones carried out in CRUMPET (Poslad *et al.*, 2001) projects have addressed the state-of-the-art and even furthered it. Recently, another clear application for supporting virtual elderly assistance communities was presented in the context of the TeleCARE project (Afsarmanesh *et al.*, 2003). Also (Corchado *et al.*, 2007)

proposed a planning agent, AGALZ, which uses case-based reasoning (CBR) architecture, to respond to events and monitor Alzheimer's patients' health care in execution time. Research on developing multi-agent systems for context aware services is increasing. For instance: SMAUG (Nieto-Carvajal *et al.*, 2004) is a multi-agent context-aware system that allows tutors and pupils in a university to fully manage their activities. SMAUG offers its customers context-aware information from their environment and also gives them a location service to physically locate every customer in the system. Another one is the BerlinTainment (Wohltorf *et al.*, 2005); the project has developed a framework for providing activity recommendations based on mobile agents. There is also a case study consisting in automating – the internal mail management of a department that is physically distributed on a single floor of a building (a restricted and well-known test environment) using ARTIS agent architecture (Bajo *et al.*, 2008).

There are also several architectures and prototypes of u-commerce systems that have been described in the literature. Shopper's Eye (Fano, 1998) implements a new set of location services enabled by location sensitive information, in a PDA or smart phones in a wireless manner. A customer's personal Shopper's Eye transmits messages to the Shopper's Eye control center. These messages detail the customer's location, goals, preferences, and related purchase history. On receipt of this information, the stores create a customized offer of goods and services. Impulse (Youll *et al.*, 2000) is another one; it is a PDA system where customers may add products to a product list, indicating preferences such as a warranty terms, reputation, availability, preferred price and time limit for the purchase. As the customer is visiting shopping zones, the user agent is in charge of negotiation and delivering efficient and effective product offerings to customers. MyGrocer (Kourouthanassis and Roussos, 2003) is a specification of the Impulse system. It is concerned with grocery shopping in large stores. There are some that not only follow the specifications of a u-commerce system, but they also integrate intelligent agents to their implementations. They are: AmbieSense project (Lech and Wienhofen, 2005) an agent-based infrastructure for context-based information delivery for mobile users; InterMarket (Kowalczyk *et al.*, 2002), which is a project aimed at the realization of an e-marketplace integrating mobile agents and intelligent decision-making agents. However, none of them combines the agents' paradigm, context-aware information with a recommendation system that can provide personalized e-services to customers.

## 3. MAS for a u-commerce based on a generic AmI MAS
The ubiquitous environments ideally fit with the agent paradigm the same way the ambient intelligent paradigm does. Multi-agent systems (MAS) support complex interactions between entities, using high-level semantic languages. Such a feature is essential in Ambient Intelligence environments dealing with heterogeneous information from physical sensors and users preferences. Integration of such data is only possible at a higher level, where all information (about context) is expressed semantically. Ubiquitous computing concepts have also reached the e-commerce environments. There are additional factors that are important for e-commerce services such as ubiquity (being available everywhere), universality (being able to operate in heterogeneous environments), uniqueness (relating services to a context such as the location) and working in unison (allowing multiple parties to work together). This type

of e-commerce has been termed u-commerce (Watson *et al.*, 2002). The design of these types of services is challenging. First of all the system must provide mechanisms for specifying, for instance, information regarding privacy preferences in a format that allows knowledge to be shared with the other parts of the system. The system must provide mechanisms to exchange privacy policies as well as to specify policy evaluation and inferencing, to determine how an information request from principals should be handled given a policy and a set of credentials. Taking into account all of the previously mentioned, we have adapted the design and architecture of a multi-agent system developed in previous works. And we have made some modifications in the previously developed ontology, in order to instantiate it to support u-commerce services provisioning.

*3.1 Ontology adequacy for u-commerce*
As in previous works (Fuentes *et al.*, 2007; Fuentes *et al.*, 2006) we have used an ontology to describe contextual information including location, profile, preferences, devices, and network etc. In this study, however, we have conceived context aware system as an interactive model between customers (shoppers) and vendors. Thus, we need to address the context description of shoppers and vendors. We have, therefore, developed two types of context ontology: shopper ontology and vendor ontology following (Yang, 2006) but we instantiate ours. We have applied Protégé (Protégé Project. http://protege.stanford.edu/) to build the shopper ontology and vendor ontology; the major difference between both ontologies lies in their profiles. The shopper ontology contains the shopper's profiles, such as personal profile, accessibility and preferences, calendar profile, social profile, and location profile; the vendor ontology contains service profiles, such as input, output, pre-condition, and effect of service execution. As we are interested in the customer's evaluation, we focused on the shopper's ontology concepts. The shopper's ontology includes the following principal concepts:

(1) *Profile*
  - *Personal profile:*
    – Name
    – Role
    – Age
    – Gender
    – Phone
    – ID
    – Address
    – E-mail
    – Situation
  - *Calendar profile:*
    – Owner
    – Event
    – Time
    – Attendee
    – Location

- *Social profile*
  – *Owner*:
    Name
    ID
    Privacy
- *Collaborator*
- *Proficiency*
- *Trust*

(2) *Location*
  - (x; y)
  - Zone

(3) *Preferences*
  - Default service
  - Default environment
  - Default quality of shopping services profile

(4) *Quality of shopping service*
  - Response time
  - Availability
  - Reliability
  - Cost

In addition to profiles, which include personal, calendar and social profile, both the shopper ontology and vendor ontology contain a surrounding context, such as quality of shopping services profile. Quality of shopping services profiles contain constraints that can be described by response time, reliability, availability, and cost. They can have values like:

- correct;
- different order; or
- incorrect.

These will later help us to evaluate whether or not the system delivers the adequate services.

*3.2 MAS adequacy and reputation system for u-commerce*
First, we present the redesign of a multi-agent system developed in a previous paper for a specific AmI scenario (see: Sanchez-Pi *et al.*, 2008b; Fuentes *et al.*, 2007). Figure 1 shows the original MAS architecture and in Figure 2 the new proposal can be seen. The redesign includes new features to support u-commerce services and applications where customers will become "shoppers" and where three new categories of agents appear: "vendor", "broker" and "positioning". For a prototype version of the Shopping Recommender System, we define three agent types as explained in last section: shopper agents, vendor agents (we have represented only two in Figure 2, but the multi-agent architecture is easily scalable to include other vendors if necessary) and a broker agent.
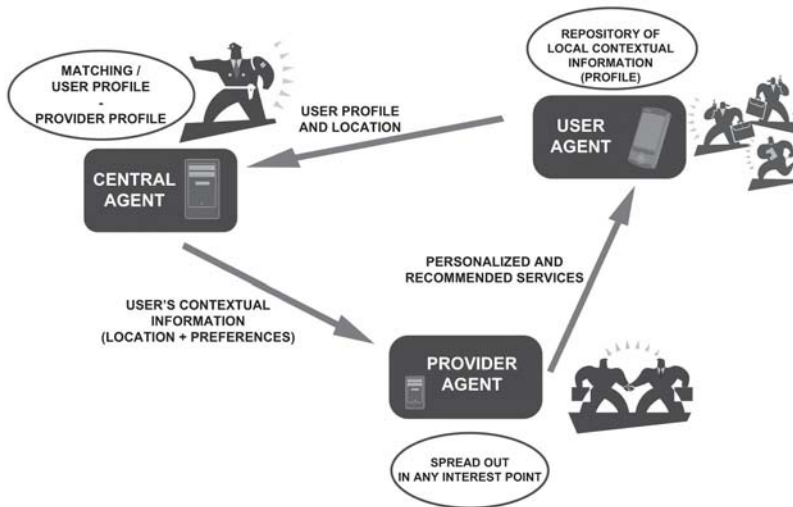
**Source:** Extracted from Fuentes *et al.* (2009)
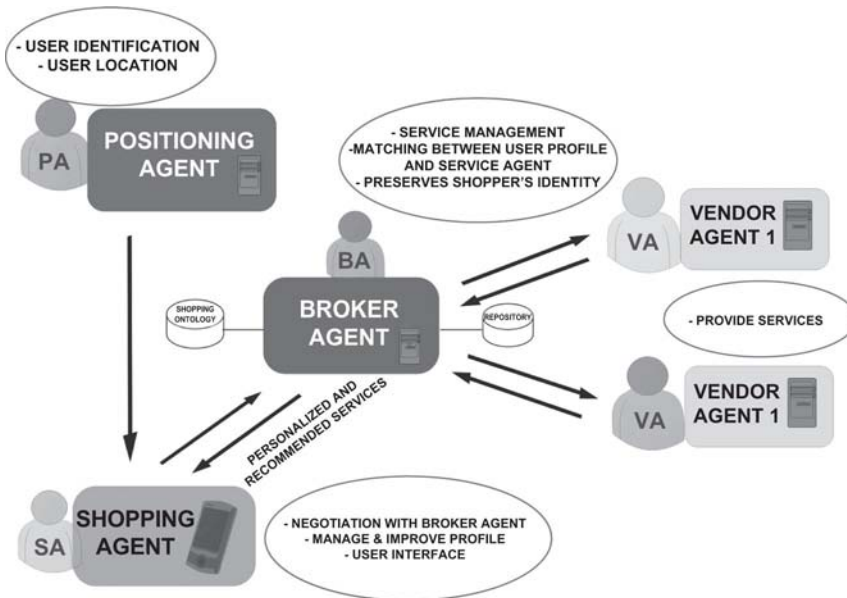
**Figure 1.**
MAS architecture



**Figure 2.**
MAS architecture for
u-commerce

As in any distribution channel, different Vendors may collaborate/compete for the provider role.

We have used the BDI agent model to specify agent architecture able to deal with environment uncertainty and with graded mental attitudes. Belief degrees represent to what extent the agent believes a formula is true. Degrees of positive or negative desire

allow the agent to set different levels of preference or rejection respectively. Intention degrees also give a preference measure but, in this case, modeling the cost/benefit trade off of reaching an agent's goal.

There is a wide variety of state of the art recommendation systems based on different criteria. Some share several of them; others are based on radically different foundations: SPORAS from MIT (Shardanand and Maes, 1995), REGRET from the Spanish Research Council (Sierra and Sabater, 2002) and an unnamed proposal from researchers at the University of South Carolina (Yu and Singh, 2000). In spite of the various aspects considered in SPORAS, REGRET and Yu/Singh, these models lack a real human-like approach. In fact, the humanization of social relationships between autonomous agents is a hot topic (Wang *et al.*, 2007) in literature because efficiency reasons proved to be insufficient to persuade human customers to delegate responsibilities in autonomous agents. A certain level of comprehension of the behavior and reasoning of agents may be also required. Therefore, several design decisions can be applied to the cooperation of agents in social networks. First, the internal architecture of agents was defined applying the beliefs, desires and intentions paradigm to buying, selling and recommending behaviors (Carbo *et al.*, 2001). The implementation of the corresponding plans depends on adaptive mental attributes. Next, cooperation between agents was formalized by messages in KQML standard (inspired in Speech-Act Theory) to ask for referrals and respond to them. Furthermore, we use fuzzy sets to represent referrals and opinions, since humans often express them in rather vague terms (Carbo *et al.*, 2001). They are also a more expressive formalism than the pair of values used in SPORAS and REGRET (opinion and its ability), or than the value of Singh/Yu. Different shapes of fuzzy sets would then stand for different levels of confidence or doubts on a given opinion about an issue/agent. Probabilistic estimations could be even more accurate, but then comprehension of human customers would be sacrificed, since humans are assumed to naturally reason with approximate reasoning rather than probabilistic reasoning. Due to the use of this representation formalism, our proposal is named A Fuzzy Reputation Agent System (AFRAS). Previous experiments (Carbo *et al.*, 2003) tested the updating of opinions not involving referrals (no cooperation was included in the model) and others involving referrals (Carbo *et al.*, 2005, 2007). They compared relative speed of convergence, the reaction to a sudden change in behavior, the improvement of recommendation quality when using referrals and the effect of malicious recommendation.

The agent system called AFRAS is designed to integrate several different features into the same _ BDI architecture: emotions through adaptive characterization of agents with sociability, susceptibility and shyness fuzzy attributes (Carbo *et al.*, 2001); security mechanisms to introduce newcomers into already formed clusters of agents with shared interests (Carbo *et al.*, 2001); ability to reach agreements through fuzzy counteroffers from crisp offers (Carbo *et al.*, 2001); privacy protection of the arguments involved in deliberative negotiations (Carbo *et al.*, 2001) and, finally, the focus of this paper: the extensive use of fuzzy sets, particularly to represent reputation values. This formalism makes sense since human opinions about others are vague, subjective and uncertain (in other words, reputation is a fuzzy concept, valued in fuzzy terms). This view is also assumed in (Falcone, 2003).

The main contributions related to the adaptation of the MAS architecture to u-commerce are:

- in the new proposal, we remove the presence of a central agent that was in charge of centralizing the information exchanged between agents;
- user agent becomes a shopper agent in the new proposal and its main goals include negotiation with vendor agents, the recommendation of services to other shopper agents, trust in other agents, and management and improvement of their internal profile to receive better services according to that profile;
- provider agents become vendor agents in the new proposal and their functionalities are closely related to negotiating with shopper agents, since they can reach an agreement with shoppers and communicate and provide the most suitable services to them, according, of course, to the shopper's preferences and profile; and
- there is a new figure in our architecture: the broker agent, whose main task is to act as a proxy between the shopper agent and the vendor agent, passing on a pseudonym in place of the shopper's real identity. This agent is also in charge of "matching" shopper's preferences and vendor's services. Selected personal information, such as the current location of the customer, can be queried by the vendor from the broker agent, using a pseudonym. A persistent pseudonym value allows the broker agent to maintain personal information for shoppers, without compromising their privacy throughout interactions with different services.

The interaction between the different agents is described by the following sequence of phases:

(1) The Aruba Positioning system discovers the customer's position when he enters the Wifi network.
(2) The positioning agent provides Aruba positioning information to the shopper agent.
(3) Once the shopper agent knows its location, it sends it to the broker agent. It also provides __ information regarding the use of a specific kind of e-service.
(4) The broker agent sends the shopper agent the identification of the vendor agent that provides the kind of e-services required by the shopper agent.
(5) The shopper agent asks a specific vendor agent to provide it with the required e-service.
(6) Vendor agent asks the shopper agent about context information to be used during the interaction to provide the personalized e-service.
(7) Shopper agent provides the required context information to the vendor agent.
(8) Interaction between the shopper agent and the vendor agent using the adaptation provided by the previous step.

## 4. Context and customer evaluation
Context is referred to as any information that can be used to characterize the situation of an entity, where an entity can be a person, place and a physical or computational

object (Schilit, 1995). There are many research efforts for the development of context aware toolkits including; Cooltown (www.cooltown.com/cooltown/index.asp), Context Toolkit (Dey and Abowd, 2000) and CB-SeC framework (Mostefaoui *et al.*, 2003). These toolkits either provide functionalities to help service requesters obtain services based on their contexts or enable content adaptations with a customer's contextual information. Context is an important issue with regard to u-commerce (Coutaz *et al.*, 2005), but when looking at ubiquitous computing systems and, in particular, context-aware systems, there are still very basic problems relating to evaluation. It is important before evaluating a system to figure out what the evaluation's goal is. In our case, the goal is to evaluate enhanced customer experience and, beyond the evaluation goal, a central concern is what to evaluate.

Qualitative evaluation should consider the customer as a central piece in the system, i.e. the customer's satisfaction levels. On the other hand, quantitative methods should objectively evaluate the contribution of context to the application.

There are several methods and approaches used to evaluate ubiquitous computing systems (Schmidt, 2002). As there are no established evaluation frameworks in literature, we first_ used a pre-implementation evaluation method, such as the "Wizard of Oz", (see: Dahlbäck *et al.*, 1993). In this method, a human mimics the computer's behavior to save implementation time. Humans are used to mimic or simulate tasks in which they're better than a computer, for instance, the prediction of behavior. And later, we used a method called "revisiting the hypotheses" (Schmidt, 2002), in which the author divides the hypothesis into four hypotheses to be investigated. First of all, some basic questions related to the context acquisition (that means that when assessing a situation, not all information is taken into account, but only the information that is discriminating), two others concerned with modeling of context (the first one: the domain context of an entity is more universal than of a complex system, suggesting building prototypes bottom-up rather than top-down; the second one: claiming that new contexts can be created when contextual knowledge is already available and that this leads to a more flexible use) and the last one is concerned with prototyping the context-aware system.

We base an offline customer's evaluation on two propositions (once the user has finished using the system and that can be accessible via: www.giaa.inf.uc3m.es/u-shopping/myfeedback/. It is also important to have an approach to the Schmidt proposal, but dynamically introduce the online customer's evaluation. It allows the customer to have dynamic access to specific context concepts in order to modify them. It also offers the possibility of proposing a modification to the reasoning algorithms and, of course, to the inference rules executed. As we can make inferences about what a customer needs, the evaluation must also take into account the correctness of our reasoning. If we draw incorrect conclusions, the customer will likely receive incorrect information. For instance, if the basic task the customer is carrying out and there is some knowledge of the information needed for that task. One possibility would be to record the situational information the customer gives about doing this particular task and take note of what actions the customer is performing at a particular time. This could be stored as part of the quality of shopping/vendor services concept in our ontology, as an historical file. It can later be analyzed through the user's opinion, which is crucial to these kinds of systems.

With regard to quantitative evaluation, customers may be measured either quantitatively, typically by defining a utility function and mapping the "satisfaction state" to numeric value, or qualitatively. The value of quality of shopping/vendor services corresponds to the user_ feedback, and can have values like:

- correct;
- different order; or
- incorrect

for every attribute (see Figure 3).

This opinion is given after he receives the ranking of the products the system recommends. We want to know whether the broker agent is a personal agent satisfying, in some degree, a set of different users. As the process of information classification is generally a complex and personal task, and may differ among individuals, we can measure the average system behavior over a population. We can then compare the inferences made by looking at the situational data and the actual customer request to draw some conclusions. The preferences and restrictions introduced by customers as input to the system, together with the system results and the user feedback, constitute our n-cases set. Each case in the dataset will be composed of:



**Figure 3.**
Online (left) and Offline (right) quality evaluation

(1) *User input*: a user ID and his graded preferences and restrictions.

(2) *Agent's result*: the system returns a ranking of a maximum of ten products and offers.

(3) *User feedback*: as explained previously, after analyzing the information of the recommended plans, the user provides feedback by evaluating the results as:

- correct;
- different order; or
- incorrect.

In order to give a general measure of the broker agent's results over the satisfactory cases, we evaluate how close the broker agent's ranking is to "the customer's own ranking. For this, we chose the Manhattan distance between the position of the first three products selected by the user and their position in the system ranking. In (Schoenharl and Madey, 2008) there is a study evaluating the applicability of several different measures to the validation of Agent-Based Modeling simulations, which is also applied in (Meinzer (2009), ed Bruijns). From a computational perspective, Manhattan distance is significantly less costly to calculate than Euclidean distance, as it does not require taking a square root. So, this distance was adopted because it has proved to be appropriate" for capturing positional differences:

$$d(\bar{p}, \bar{q}) = \sum_{i=1}^{n} |p_i - q_i|$$

If we assume the quality of shopping agent (which is the user's feedback) is $Q_i = (P_{i1}, P_{i2}, P_{i3})$ and the broker agent ranking for this consult is $R_i = (R_1, R_2, ..., R_9)$. Then, if $P_{i1} = R_j$, $P_{i2} = R_k$, $P_{i3} = R_n$, the distance between the customer's and the system rankings is defined by:

$$Dist(Q_j, R_j) = |1 - j| + |2 - k| + |3 - n|$$

In reference to the quality of information, user' feedback can be expressed by writing a comment about the satisfaction or dissatisfaction experienced with regard to a particular aspect, or with a suggestion to improve the feedback. Both quantitative (e.g. effectiveness, efficiency, user satisfaction, and workload) and qualitative (e.g. user comments) data were obtained from the user.

So our system could then:

- discriminate between contextual information;
- allow customers to rewrite the concept "quality of shopping service" described in the ontology (which will be mapped to obtained a quantitative evaluation);
- allow customers to make personalized annotations and leave them – in the current location (qualitative); and
- introduce a new concept in the ontology, such as the situational information concept described previously.

## 5. U-commerce in an AmI scenario

In this section, we illustrate our multi-agent context-aware system for a u-commerce scenario:

(1) *User name*: John Mayer

(2) *Location*: Parquesur Shopping Center

(3) *Date and time*: 2009-12-14, 17:00

(4) *Device*: PDAQ 00-18-41-32-0B-59

(5) *Objective*: To buy some new clothes, find new offers.

A young customer "John" goes to "Parquesur" shopping mall because he needs to buy some new clothes. Every store into the shopping mall hosts a vendor agent that is used to interact with shopper agents in order to suggest and offer the best product to the clients using the broker agent. Once in the shopping mall, they immediately connect their wireless PDAs to Parquesur's wireless network. Once connected, the shopper agent (used to provide a way to interact with the client (through a GUI)) is installed into the PDAs and begins the registering process. The Broker agent then assigns a pseudonym to the shopper agent to preserve its identity (see Figure 4).

In the case of John, who is a new client, the broker agent emits some required questions to register an initial minimal by means of a preference questionnaire. Other additional data can be included in the profile, but will be considered optional, such as: address, phone, email, and ID number. John, however, decided not to respond, although some of this would be considered private information, and, therefore, would only be used internally, by the shopper agent to provide a customized filter of the services offered by vendor agents. Next, the broker agent asks the shopper agent these and other questions related to the preferences connected with the current shopping activity, such as: gender, age, clothes, shoes, and jewelry.

Once Receive-registry-profile protocol has concluded, the broker agent evaluates its position and computes the geographical proximity to the location of different vendors' agents offering the shopper's agent the possibility of downloading a discount coon for using our systems. Calvin Klein's vendor agent is the closest to John's location, so the broker agent notifies it about the presence of John's shopper agent with the "Notify agent" protocol. When Calvin Klein's vendor agent has been notified, it will provide its particular offers and customized suggestions – according to the context exchanged with the broker agent. After that, a negotiation included in the offer-service protocol takes place in order to reach a possible agreement about services. For instance, Calvin

```
Shopper agent named JohnMayer running...
Shopper agent named JohnMayer receives message 01 with its location

(INFORM
:sender(agent-identifier:name ParquesurShop@giaa-uc3m-ns:2010(JADE)
:receiver(set(agent-identifier:name JonhMayer@giaa-uc3m-ns:2010(JADE)
:content((HasLocation(agent-identifier:name JonhMayer@giaa-uc3m-ns:2010(JADE)
:language fipa-s10:(ontology shopping-ontology:conversation-id m01)

Shopper agent named JohnMayer has correctly read message 01
```

**Figure 4.**
Processing of location information provided by the corresponding agent

Klein's vendor agent makes a match – between John's preferences and the concepts stored in our ontology and immediately informs the shopper agent about two types of jeans, model A, model B.

John is surprised by the vendor agent's suggestions, because both of them are for women's jeans, so he uses the customer evaluation interface to make some annotations in the parameters of "quality of shopping service" icon present in the GUI to introduce a value in the "reliability" field, which remains as a historic field. The Vendor agent then informs the broker agent about the misunderstanding, and then broker agent asks the shopper agent to fill in the optional fields of the preferences questionnaire. It is then that the gender field is filled out and "the system can suggest the proper information to the shopper agent".

Later, John arrives home, sits in front of the computer, opens the browser and connects to www.giaa.inf.uc3m.es/u-shopping/myfeedback. He logs-in and selects from the category of "shopping malls", the one he has visited recently. He clicks on the specific store he wants to comment on and evaluates the contextual information he received by means of an e-service in a certain place. A picture of the front of the store appears, confirming its location and coordinates. Finally, the system response is shown to the customer as a text message (i.e. "jeans recommendation"), so he can then proceed to fill in the quality parameters according to the system response. See Figure 5.

If $P_{i1} = $ "effectiveness", $P_{i2} = $ "efficiency", $P_{i3} = $ "user general satisfaction", $P_{i4} = $ "workload"; identified as quality parameters $Q_i = (P_{i1}, P_{i2}, P_{i3}, P_{i4})$ and the vendor agent ranking for this consult is $R_i = (R_1, R_2, \ldots, R_9)$ given by the customer. Then, we can calculate the distance between the customer and the system

The frequencies of the Manhattan distance, corresponding to the broker agent results for the satisfactory cases as well as the unsatisfactory cases, can be analyzed to draw some conclusions and give this feedback to the system.

# 6. Conclusions and future research agenda

U-commerce emerges as a continuous, seamless stream of communication, content and services exchanged among businesses, suppliers, employees, customers, and products (Accenture, 2001). It enables interactions and transactions to happen anywhere and at any time. U-commerce affects many aspects of business, and due to the lack of research, in the area of u-commerce, there are research issues and challenges that need to be tackled. The challenging issue of personalization is one of them, and it is dependent on two factors: first, companies' ability to acquire and process customers' information, and second, customers' willingness to share information and use personalized services (Chellappa and Sin, 2005). Companies would like to obtain as much information as possible about their customers so that they can provide them with personalized products or services and maximize their profits. That is why we think the approach to intelligent agents is an important issue, as these represent a logical choice for the use of intelligence in the u-commerce applications. Our challenge, then, comes from the idea of offering an intuitive and conceptually simple model based on agents in which customers needs and preferences can be represented in a transparent way, and in which customers logged into the system can receive adequate e-service and give important feedback to the system, so agents can learn from user experiences.
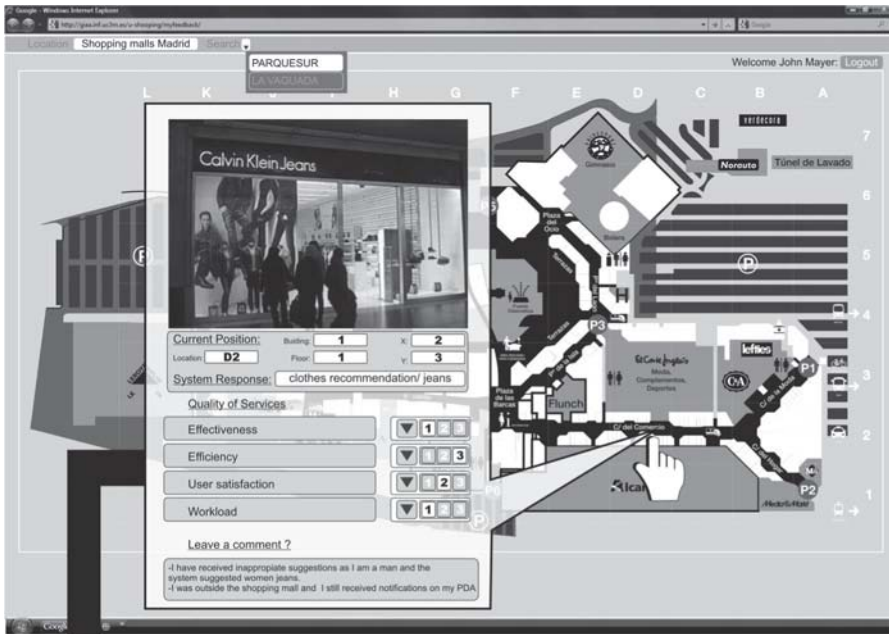
```
<html>
<head>
<title>Customer evaluation HTML</title></head>
<body>
<quality> effectiveness=1 efficiency=3 user
satisfaction=2 workload=1 comment="I was outside
the shopping mall and I still received
notifications on my PDA</quality>
</body>
</html>
```

**Figure 5.**
Offline customer feedback
through: http://giaa.inf.
uc3m.es/u-shooping/
myfeesbak and its html
representation

However, in spite of the benefits of u-commerce applications, these also have limitations, and raise many new questions with regard to privacy, trust, and security.

In addition, the deployment of u-commerce in the real world has implications beyond the technically obvious ones: social, economic, legal, etc. The personalization-privacy paradox (Awad and Krishnan, 2006) suggests that customers need to reveal some of their personal information in order to receive personalized services. Therefore, as part of a future project, we plan to extend this research, to measure the perceived benefits of personalization vs non-personalization, and compare results in different environments, examining the benefits of using a multi-agent system architecture in which customers are represented by agent entities.

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